‘Management of the Environment’

Reading Material

Training Programme for IAS Officers

September 01-05, 1997

Organised by

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Programme Schedule for IAS Officers Training Programme on "Management of Environment," September 1-5, 1997

Day /Session	0930-1045		1100-1210	1210-1320		1400-1515		1530-1700
Monday 1st September	**0930-0945** Regis-tration **0945-1045** Overview of State of India's Environment-*Dr. L Srivastava (TERI)*	**T**	Economic Instruments for Environmental Management-*Prof. S Gupta (D School of* Economics)	Environmental Law Mr. *Chattrapati Singh*	**L**	Valuation of Environment-*Mr. Sudhir Sharma (TERI)* & Environmental Accounting-*Mr. Vikram Dayal (TERI)*	**T**	Sustainable Development of large dams; the Narmada case study *Mr.Sripad Dharamadhikary(NBA)*
Tuesday 2nd September	Water Pollution- *Dr. Makhijani (CPCB)*		Water Resources Management- *Mr. R B Shah (CES)*	Wastelands Development-*Mr. Arvind Khare (IGCMC/ WWF)*	**U**	Air Quality Status and Management - *Mr. S Saksena (TERI) & Dr. B Sengupta (CPCB)*		Industry and the Environment - *Mr. K P Niyati (CII)*
Wednesday 3rd September	**0915-1015** Applications for Environmental Management-*Dr. Bhujanga Rao(TERI)* **1030-1120** Travel to Gual Pahari	**E**	**1130-1215** *Mr. Sanjay Prakash (DAAT)*	**1215-1330** Forestry- *Dr. T P Singh, Dr. Kinsuk Mitra and Dr. J S Rawat (TERI)*	**N**	**1415-1600** Biotechnology: Its role in Environmental Management & Visit to TCPP *Dr V.Dhawan* (TERI)	**E**	**1600-1700** Return to Delhi
Thursday 4th September	Green Rating System -*Ms.V Bhatnagar (TERI)* & Green budgeting -*Mr Vikram Dayal* (TERI)		Environment Impact Assessment & Management- *Mr. P V Sridharan and Dr.Subrato Sinha (TERI)*	Financial Instruments for Sustainable Environmental Management-Mr. Hari Sankaran *(ILFS)*	**C**	People and the Environment - *Mr. Ashish Kothari (IIPA)*		Development of Institutional Mechanisms in Environmental Management- *Dr. Dilip Biswas (CPCB)*
Friday 5th September	Management of Fuel Emissions in the Transport Sector- *Dr. Geetam Tiwari (IIT), Mr. K K Dhingra (PCRA), Ms Kiran Dhingra & Mr. S Sunder (TERI)*	**A**	Climate Change & Montreal Protocol-*Dr. A Mathur &* Convention on Biological Diversity: An Introduction-*Ms. Amrita Achanta(TERI)*	Integrated Env. Planning: Case study of ADB Agra Trepezium Project - *Ms. S M Asher, Resident Representative, ADB and Dr R K Pachauri, Director, (TERI).*	**H**	Valedictory Session	**A**	Course evaluation

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Economic Incentives for Cleaner Production in Industrializing Countries

Prepared By:

Environmental Pollution Prevention Project (EP3)

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1.0 INTRODUCTION

Rapidly industrializing countries are experiencing a significant increase in air pollution from both fixed and mobile sources, deteriorating water quality, soil erosion, inadequate sewage facilities and other environmental infrastructure, a rise in the quantities of both solid and hazardous wastes generated by the industrial sector, among other pressing environmental and conservation issues. Traditionally, governments have responded to declining environmental quality through a "command-and-control" approach to environmental regulation which includes establishing environmental standards, issuing permits, and enforcing these measures through sanctions. Although this approach has been very effective for managing some environmental problems, industrializing countries are often faced with pressures to develop their industrial sector rapidly, often at a cost to the environment. Increasingly, the use of economic incentives is being promoted as a means to balance economic development with environmental protection.

The use of economic incentives was recognized at the global level in 1992 at the UNCED conference in Rio de Janeiro. Principle 16 of the Rio Declaration on Environment and Development states:

> National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.

Agenda 21 also addresses economic incentives stating in Chapter 8, that "within a supportive international and national context and given the necessary legal and regulatory framework, economic and market-oriented approaches can in many cases enhance capacity to deal with the issues of environment and development..." It also encourages the effort to make more widespread use of market-oriented approaches within country development policies. While most industrialized countries have had some experience with economic incentive policies related to environmental protection, the use of these policies is clearly growing worldwide.

This report presents an overview of economic incentives for environmental protection and discusses how they have been applied for a variety of environmental issues. Section 2 presents the concept of economic incentive mechanisms. It is important to recognize that by the very nature of economic incentive mechanisms, they can encourage pollution prevention, resource conservation, materials savings, technological innovation, and overall sound environmental practices; however, they cannot always guarantee that a specified objective will be achieved. Thus, Section 2 also discusses the use of economic incentives in the context of a regulatory and economic framework and highlights the important elements that should be considered when developing economic incentive policies. Section 3 discusses individual economic incentive mechanisms more in depth and provides examples of how they are being used throughout the world today. This overview is meant to provide an overview of all types of incentives mechanisms with an emphasis on those that are in place in industrializing countries. Under the auspices of the Environmental Pollution Prevention Program, further work will be done on examining specific economic incentive mechanisms that promote pollution prevention.

2.0 OVERVIEW OF ECONOMIC INCENTIVES

Governments have traditionally sought to protect the environment through a "command-and-control" approach (CAC) to environmental regulation. With this approach, the government either specifies an "end-of-pipe" pollution control technology that must be used or an emission-rate cap that all sources must meet in order not to exceed an established health-based standard. Permits, prohibitions (e.g. dumping hazardous wastes), monitoring protocols, and reporting and record keeping requirements also comprise part of a CAC structure. Sanctions are used as a negative incentive or disincentive to enforce these measures. Although CAC regulations have been effective in industrialized countries in addressing major environmental pollution and health hazards, this approach has many drawbacks. For example,

- it can lead to inefficient pollution abatement measures and is costly for both firms to comply and government to administer
- it relies on sophisticated enforcement procedures and litigation
- it can be overly bureaucratic
- it tends to emphasizing "end-of-pipe" reductions and often encourages simply shifting the environmental hazard from one environmental medium to another (e.g. from air to water).

Especially with regard to pollution prevention, a fundamental drawback to CACs is the lack of incentives to substitute inputs or change processes that reduce the quantity of pollution created. Governments, by emphasizing "end-of-pipe" reductions, have encouraged firms to continue using harmful inputs and processes rather than adopting clean technology or developing innovative solutions to prevent pollution. As environmental resources are becoming more scarce this limitation of CAC "end-of-pipe" regulations, as well as the aforementioned ones, is becoming clear.

Economic incentives, on the other hand, strive to integrate environmental and economic concerns. They seek to harness the power of the market to achieve environmental goals by turning the market from an adversary of the environment into a powerful ally. They can achieve environmental objectives not by mandating prescribed actions, but by changing the economic incentives facing producers and consumers. Economic incentives take full advantage of the information possessed by polluters without requiring disclosure of that information or the establishment of a large and costly bureaucracy. In many areas, economic incentives can make economic development the vehicle by which greater environmental protection is achieved (Panayotou, 1995).

Policies that successfully protect the environment and support sustainable economic development require businesses, governments and households to modify behavior, and, at times, endure short-term economic sacrifices for long run gains. For example, firms must devote capital to install new equipment, modify older technologies or change production processes to reduce harmful by-products. In industrializing countries, the demands for rapid economic growth are compelling, but the ability to pay for cleaner production is often limited. Leaders are under remarkable pressure to implement policies that provide maximum environmental protection at minimum cost and reduce the degree to which such policies inhibit economic growth (OECDa, 1992).

In situations where individuals and businesses bear all the cost and benefits of their decisions affecting the environment, there is no need for government intervention. However, as part of their cost minimization strategies, polluters typically seek others to bear the costs of environmental degradation. Intervention is needed where firms are imposing costs on others who bear the consequences of those costs, but who cannot prevent such damage or gain compensation from it (OECDa, 1992). In implementing an environmental policy, policy makers should consider questions of equity, efficiency and effect, or more to the point, who pays for environmental protection and how much do they pay. To achieve an efficient and equitable environmental policy, the following should be taken into consideration (EPA, 1991):

- the risks associated with continued environmental degradation
- the health, ecological, environmental and economic costs and benefits involved to ensure the benefits of abatement are greater than the costs
- application of the "polluter pays" principle
- whether an approach that emphasizes cleaner production instead of "end-of-pipe" pollution abatement.

One way to incorporate these policy goals is to use economic incentive mechanisms. Designing and implementing an environmental policy using an economic incentive approach can lead to greater equity and efficiency in pollution control. In many cases, economic incentives can also be integrated into the existing command-and-control structure to best take advantage of the strengths of each approach. The remainder of this section discusses the issues related to the use of economic incentives for environmental protection.

2.1 ISSUES ASSOCIATED WITH THE USE OF ECONOMIC INCENTIVES

2.1.1 Proper Pricing for Sustainable Development

The notion of sustainable development is based on the idea that the capital stock of a country should not be depleted without compensation to future generations. This implies, in essence, that development should leave future generations as well off as current generations. While this notion extends to environmental resources, these resources are not typically included in national income accounts because they are not treated as productive assets and depreciated overtime as is other capital (e.g equipment). The use or depletion of these resources is treated as current net income (e.g., income from harvesting of trees), without an offsetting calculation of the depletion in the basic capital stock. This results in an illusory gain in current income, at the cost of a permanent loss in national wealth in the form of environmental resources. As countries industrialize, it is increasingly important that environmental resources be included in a nation's capital stock and their value be captured in national income accounts.

Incorporating environmental resources in national income accounting encourages the proper pricing of resources which provides signals to economic agents (e.g. individuals and firms) to act in manner that is consistent with sustainable resource use. Over the long term, this will stem the overuse of environmental resources and preserve future productive capacity. Economic incentives to encourage cleaner production are designed to further the goal of sustainable development by helping to value the environment at its true productive worth and incorporate it into the economic system.[1]

2.1.2 Encouraging Technological Innovation

An industrial economy can be likened to a machine that profits by transforming raw materials and energy into products. In a competitive marketplace, individual businesses carry out this function in ways which tend to maximize their individual productive efficiencies. They strive to continually reduce the costs of acquiring and using raw materials, energy, labor and other resources. Pollution, therefore, is a sign of inefficiency (waste),[2] where raw materials and energy are incompletely transformed into products or services (Shireman and Cobb, 1994). In theory, a competitive economy should eliminate pollution over time, as individual business strive to increase profits. In practice, economies suffer from market failures and externalities which shift the burden of pollution away from the polluter and create incentives to continue inefficient production practices.[3]

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[1] For more information on sustainability please refer to Munsingahe (1993) and Munsinaghe and Cruz (1995).

[2] The total waste of a country can be described as: **W = (Waste/GDP) (GDP/Capita) (Population)**, government polices that increase industrial output without first reducing the waste/pollution per unit of GDP will only worsen environmental problems. In order to reduce environmental and health problems in real terms, the waste per unit of GDP must decrease to compensate for growth in economic activity and population.

Waste reduction and improvements in efficiency can be achieved through newer, or "clean," technology that uses inputs more completely. Through technological innovation, firms can adopt processes that use inputs more efficiently, thereby lowering their production costs (through using fewer raw inputs and energy) and reducing waste and harmful discharges. Overall, market signals play an important role in driving the rate and direction of technological change. Where there is the possibility of an increase in profit resulting from a new technology, it is likely that it will be adopted.

Except for the threat of sanctions for lack of compliance with environmental regulations, firms have little incentive to invest in "end-of-pipe" pollution control equipment because it does little to improve productivity. Therefore, for the firm there is an apparent gain in capital efficiency (or capital savings) by not investing in pollution control technology. This gain masks the total productivity loss due to continued environmental degradation. Since waste discharges are usually underpriced or, in many cases, unpriced, few market incentives exist to seek and adopt waste-reducing technologies, unless they are incidental to other cost savings (i.e., reduced raw material costs). The profit-seeking firm has an incentive to reduce costs at the expense of increased environmental damages, because these damages are not born by the firm. While CACs create a disincentive for the firm to internalize pollution costs, and hence the need to develop more efficient technology,[4] economic incentives can provide incentives for adopting clean technology.

2.1.3 Macroeconomic Conditions

The success of economic incentives for environmental protection is closely linked with a country's overall macroeconomic conditions. Two important policy failures in economic systems with important environmental ramifications are institutional policy failures and short-sighted macroeconomic policies (policies that give more priority to immediate concerns at the expense of long term sustainability). For example, high levels of government intervention in Eastern Europe have resulted in serious and sustained environmental degradation whereas in Latin America and Africa policies to deal with financial instability, inflation, fiscal crises and foreign exchange problems have undermined long term growth and have often been enacted at the expense of the environment. Overall, macroeconomic conditions have been unfavorable to investment and maintenance activities in both material (capital stocks) and environmental resources in industrializing countries.

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[3] The works of Apgar and Brown (1987), Varian (1987) and Titenberg (1992) all contain in depth descriptions of externalities and their economic foundations. Their texts contain the theoretical background for the "efficiency" argument for economic incentives.

[4] The rate of technological change is therefore an important criterion on which to evaluate a regulatory policy. A successful policy will encourage firms to invest in pollution control technology. The available evidence suggest that existing environmental policies (i.e. CACs) have provided little stimulus for change and innovation in pollution control areas. Research and development expenditures for pollution control technologies in the U.S. (1990 data) averaged between 2% and 3% of total revenues (API, 1990).

Policies on interest rates, credit, subsidies, investment and growth all have important effects on the environment. Given macroeconomic stability and appropriate incentives, ecological damage from industrial activity can be significantly reduced (Anderson, 1990). This implies that a growing economy does not have to result in increasing environmental damage. Macroeconomic stability is a key element in reducing environmental degradation, and is essential in supporting economic incentive policies. Incentive policies need a strong and relatively distortion free market in which to function.

In many cases government policies such as subsidies exacerbate existing market failures. Many governments heavily subsidize irrigation water, undermining farmers' incentives to adopt often simple and economic technologies to conserve water. Overall, water use efficiency is drastically reduced and as a result rivers, wetlands, groundwater, and soils suffer significant losses in productivity. Tax, credit, pricing and other policies also often discourage resource conservation. This reduces economic productivity and increases fiscal burdens on government. Producer incentives are often biased toward degradation of the resource base, and potentially more efficient production systems are discouraged (Repetto, 1990). When considering the implementation of economic incentives, it is essential that policy makers take a broad look at the country's tax and subsidy policy and take steps to alleviate those that impede the proper functioning of the market.

2.2 DRAWBACKS OF COMMAND-AND-CONTROL REGULATION IN INDUSTRIALIZING COUNTRIES

In developing their environmental regulations, many industrializing countries have followed the path of the U.S. and Europe in developing a command-and-control regulatory structure. While this approach has been successful in addressing many environment, the drawbacks mentioned previously are often more pronounced in industrializing country. The section highlights some of the key issues that weaken a command-and-control regulatory approach.

- **Enforcement:** The ultimate command-and-control measure is the sanction. Environmental regulations in many countries stipulate terms of imprisonment and/or fines for non compliance or violations. However, in many industrializing countries (most notably in Asia) courts are used as a last resort. As this is often common knowledge, regulations can become nothing more than "paper tigers." While many countries have an extensive body of environmental regulation, they have little chance of effectively reducing environmental degradation (OECDa, 1992). Many industrializing nations have stricter standards than industrialized nations, but the lack of enforcement results in continuing environmental degradation. Hand in hand with the difficulties in enforcing CAC regulations is the "rent-seeking" behavior they engender. Rather than pay the fine owned to the government, violators may, in some cases, pay a small portion of the stipulated fines as a bribe to the enforcement official who, generally being underpaid, is prone to accept it. Increasing fines or enforcement often only increases bribery.

- **Monitoring:** A difficulty in implementing an effective CAC policy is the numerous small scale operations (often widely dispersed geographically in remote areas) that individually generate little pollution, but taken together they account for the bulk of pollution in a country. It is difficult to monitor and enforce small, dispersed pollution sources. CAC regulations place the burden on government to monitoring these smaller firms, yet there is a clear disparity between the high regulation, monitoring and enforcement needs of CACs, and the budgetary, manpower and administrative constraints of government.

- **Political Interests:** CACs are the instrument of choice for most governments. Regulations, unlike economic incentives, are written in precise language that carries with it the threat of punishment. Strict regulations are attractive to politicians who promise to protect the environment, and industry does not strongly object because it knows the penalties are rarely enforced. Occasionally, a flagrant violator can be treated as a scapegoat, creating the impression that government is tough on environmental crime. CACs can also hide the true cost of environmental protection from the public, because regulatory costs are less obvious to the taxpayer and the consumer (OECDa, 1992).

- **Unequal Costs**: Under a CAC strategy all firms typically face uniform regulatory standards with which they must comply. This assumes homogeneity among firms and does not allow for differences in abatement costs; however, the cost of controlling a given pollutant may vary by a factor of 100 or more among sources, depending upon the age and location of plants and the available technology (Stavins and Whitehead, 1992).

- **Need for Sophisticated Technical Information:** Some standards specify a certain type of technology that must be used instead of allowing firms to decide for themselves which control or prevention technology would be appropriate in their facility. Specifying specific technologies demands that

> regulators become well-versed in the industrial processes they are regulating. The information needs of many CACs create the need for costly bureaucracies and expensive monitoring and enforcement. This increases the overall cost of pollution abatement to society (Baumol and Oates, 1988), a cost which many industrializing countries can ill-afford.

While the issues raised in this section can limit the application of CACs in both industrialized and industrializing countries, the type of government in a country is also a determining factor. For example, of the major industrial Asian countries, Japan and Korea rely heavily on CAC. The continued appeal of CAC in Korea may be due to the industrial structure, where a small number of large firms (the Chaebol) account for a majority of industrial output and its joint product pollution. In this industrial structure a targeted approach that focuses on the worst offenders can be effective and monitoring costs relatively low. In Japan, the close government-industry relationship may permit a more dynamic regulatory policy that can focus on cleaner production as a means to reduce pollution instead of "end-of-pipe" standards (OECDa, 1992). On the other hand, Taiwan and Thailand are more inclined to use economic incentives. There are more small and medium-sized firms dispersed over a large area making a traditional CAC approach unfeasible.[5] They already have a basic regulatory framework in place that defines environmental quality standards. The greater acceptance of economic incentives in these countries is consistent with the smaller government role in economic management traditionally found in these countries (OECDa, 1992).

Worldwide, traditional command-and-control strategies are providing to be limited in their ability to affect environmental practices and stand little chance of success to achieve true environmental gains in the long run. Innovative approaches are necessary to correct the environmental exploitation associated with expanding economies. In order to achieve prosperity the environment must be protected. Using economic incentives, an incorporating them into existing CAC frameworks, can encourage cleaner production and waste minimization and help to create strong economies capable of sustaining economic growth.

3.0 THE APPLICATION OF ECONOMIC INCENTIVE MECHANISMS

This section presents the different types of economic incentive mechanisms and provides examples of how they are being used throughout the world. In this report, economic incentives are divided into three principal categories: 1) price based incentives, 2) quantity based approaches, and 3) a "catch-all" category for a host of ancillary policies that fall within the broad concept of economic incentives. Price based incentives include: emissions, effluent, product and user taxes, fees or charges. Quantity based approaches (market creation systems) include: tradeable permits, concessions and auctions. Among the other incentive policies are subsidies, tax breaks, liability schemes and voluntary compliance programs. All economic incentives attempt to integrate the market and the environment.

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[5] As mentioned earlier, the number of firms and the geographical dispersion makes monitoring and enforcement activities administratively burdensome and costly.

3.1 THE OBJECTIVES OF MARKET BASED INCENTIVES

The regulatory power of government is likely to be a driving force behind cleaner production and products. Policies must evolve so industry is motivated by the market, which is backed by regulatory threat. The main objectives of an environmental policy that promotes cleaner production should encourage (OECDb, 1992):

- in process recycling
- the re-use or recovery of as many inputs as feasible
- the modification of segments of the productive process itself
- the substitution of inputs,
- the alteration of the end product itself.

The ability of an individual company to deploy cleaner production technologies depends upon the nature of the firm's industrial processes; size and structure of the firm; attitudes and opinions affecting operations of the firm; information available for cleaner production technologies; and current regulations and their enforcement (OECDb, 1992).

When the economic and social costs of acquiring and using resources are not fully accounted for, these costs are externalized by the businesses or individuals directly responsible for them. Economic incentives seek to isolate these "externalized" costs of productive processes and require the firm or individual to "internalize" them. This encourages a full account of all benefits and costs so that individual firms maximize profits inclusive of environmental damage. Essentially, economic incentives attempt to impose costs and extend ownership to each unit of pollution and waste. Any increase in pollution then leads to higher costs and lower profits. Additionally, any decrease in pollution leads to lower costs and higher profits.

Economic incentives, as instruments of environmental management in industrializing countries, have many advantages over CACs. They can achieve the desired results at the least possible cost which is vital to industrializing countries with limited resources and a dire need to maintain their competitiveness in world markets. Economic incentives are easier to enforce which is important in countries with limited enforcement capabilities. Economic incentives present fewer opportunities for rent-seeking behavior than regulations, and therefore they are likely to be both more effective and more equitable. Finally, unlike regulations that require large bureaucracies and budgets, economic incentives generate revenues which should be welcomed by countries facing tight budgets and deficits.

Five principles that should be considered in the development of economic incentives (OECDb, 1992)

- ***The ambient quality target*** - Flexibility of response is important, but the aim should be the achievement of an environmental quality (ambient) standard. The target ambient quality standard should be specific, monitorable and verifiable.
- ***The minimum cost principle*** - The desired ambient quality standard must be attained though the most cost-effective means (the lowest possible cost to the economy)..The costs should include monitoring and enforcement costs to the regulatory agency and output reduction and pollution control costs to the industry.
- ***The polluter pays principle*** - The chosen policy instrument must be self-financed, and equitable. While the payment is collected from the industrial producer, the ultimate burden (incidence of the pollution charge) is shared between the producer and the consumer in a proportion determined by the elasticity of demand for the product in question.
- ***The competitiveness imperative*** - The policy instrument chosen should minimize any reduction in the overall competitiveness of industry, although it would unavoidably change the industrial mix in the medium to long run, if it is effective.
- ***Policy transition*** - Changing the industrial mix from high to low polluting industries is one of the desirable outcomes of an effective pollution control instrument. Structural change takes time. Allowance for adjustment during the transition period must be made. The stability and predictability of the policy is crucial if industrial investment is to be gradually shifted from high to low polluting industries.

3.2 OVERVIEW OF INCENTIVE MECHANISMS

This section presents an overview of these incentive mechanisms and the characteristics that distinguish price based incentives, quantity based incentives and the "catch-all" incentives categories.

Price Based Incentives: Price incentives try to integrate the costs of pollution into production or consumption decisions by raising the costs of the environmental use or input. Incentives try to raise the cost of using the environment in order to capture more of the value of the resource being used. These include taxes, fees and charges that are placed on the quantity or quality of discharges from a production facility.

- **User fees** are payments for public treatment facilities. They are most often used in the collection and treatment of municipal solid waste and for the discharge of wastewater into sewers (OECD, 1992a).

- **Effluent and emissions charges** (also called pollution charges) are based on the quantity of discharges. A discharger is required to pay a certain amount for every unit of pollution discharged into surface water or emitted into the atmosphere. Generally they are used in conjunction with standards and permits. These are readily integrated with existing standards and are the most widely used economic incentive mechanisms.

- **Product charges** are based upon the potential pollution of a product. They function like effluent charges in that they allow users to determine the most cost-effective means for reducing pollution. For example, a product charge could include a charge on lubricating oils, non-returnable containers, fertilizer and pesticides (OECD, 1992a).

- **Input taxes** are applied to productive inputs that are thought to contribute to environmental problems. For example, a tax can be levied on the carbon or sulfur content of coal. These taxes are linked to the quantity of a harmful input used in production. They work by raising the price of the harmful input, which makes its use less desirable to the profit maximizing firm.

- **Deposit/refund systems** work by adding a refundable deposit to the purchase price of a new product. For example, a consumer who purchases a lead acid battery and does not return it when purchasing a new battery would, in effect, see the deposit as a fee that would not be paid if a used battery were returned. This then provides an incentive for consumers to return the product in order to receive their deposit. A deposit/refund system should be largely self-policing. The deposit/refund provides an economic incentive when the spent product is returned for disposal (EPA, 1991).

- **Tax differentials** provide a more favorable price for "green" products. Usually two surcharges are levied onto other product charges. A positive charge on a polluting product and a negative charge on a cleaner alternative. Differential taxing of leaded and unleaded gasoline is an example (OECDa, 1992).

Quantity Based Approaches: These approaches attempt to restrict the available quantity of an environmental resource and extends the market (via property rights) to the resource so it is more accurately valued in economic decisions. They work by creating scarcity for the "good" (e.g., the air mantle or a water course) resulting in an increase in the price of the "good," making it less attractive to a profit maximizing firm.

- **Marketable permits** work by setting the maximum amount of pollutants allowed, as in a traditional approach, but then allows firms to "buy" units of pollution. There is an initial allocation of permits which specify the type and quantity of pollution allowed to be discharged. This creates a finite amount of pollution, which then creates "scarcity rent" for the "good." Each firm is allowed to buy and sell the discharge rights.

- **Concessions** are basically a permit system generally applied to forest or mine reserves. They allocate, for a fee, the amount of the resource allowed to be extracted. These can have a powerful incentive effect if the fee charged per concession is high enough to discourage use of the resource. Concessions attempt to extend property rights to common property resource in order to increase its scarcity rent.

- **Auctions** are very similar to the tradeable permit schemes. They specify a given quantity of the resource, thereby limiting its availability which increases its value. The regulator decides the quantity of the resource to be used and brings together buyers of the resource who bid until the "market clearing price" is reached (ADB, 1994).

Other Economic Incentives: There are a host of other economic incentives that can be applied to environmental problems in industrializing countries. These tend to be more tied to the traditional command-and-control approach, but, broadly defined, they provide an economic motivation for better environmental and conservation practices.

- **Enforcement incentives** are tied directly to regulations. They are designed to encourage dischargers to comply with environmental standards and regulations. Enforcement incentives include noncompliance fees or fines, performance bonds and liability assignment. They also include denial of public subsidies and partial or total suspension of plant operations.

- **Noncompliance fees** are levied against a discharger that exceeds standards imposed by regulators. These are used when CACs are the primary method for environmental protection, when enforcement is weak and when it is cheaper to impose fines than to engage in costly litigation procedures. They provide a monetary incentive for firms to obey regulations by making it costly if they are caught exceeding pollution standards.

- **Performance bonds** are payments made to regulatory authorities before a potentially polluting activity is undertaken. The payments are returned when the environmental performance of the activity is acceptable. It allows a firm to use innovative techniques and processes without having to await government supervised tests or regulations.

- **Liability assignment** provides incentives to actual or potential polluters to protect the environment by making them liable for the damage they cause. This ensures that victims of environmental damage are compensated. It also provides the polluter with the assurance that the costs of any environmental degradation will be duly assigned. The burden of proof is placed upon the polluter to prove the discharge harmless.

- **Voluntary Compliance Schemes** mainly function as offensive actions by industry in response to perceived threats of stricter environmental regulations. These agreements rely on moral suasion and self-policing to affect behavioral changes in polluting enterprises. They specify what measures a firm is willing to take to prevent or mitigate pollution and the time frame for implementation. A company which values positive public relations with the local community may have a strong incentive for voluntary compliance. The Chemical Manufacturer's Responsible Care program is an example.

3.3 PRICE BASED INCENTIVE MECHANISMS

A price based incentive provides motivation for firms to reduce polluting behavior at any level that causes their marginal abatement costs to exceed the tax or charge. Pollution poses real costs to society in the form of deleterious health effects, property damage, various aesthetic impacts and ecological damage (i.e., lost species and habitat). Traditionally, firms have not had to pay for these damages and have had little incentive to consider them in production decisions.[6] Price based incentives force firms to pay for the external costs of pollution, inducing firms to internalize externalities.[7]

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[6] In many cases, firms have had a disincentive to reduce pollution because it increases costs which puts that firm at a competitive disadvantage. It is more profitable to pollute when a market failure exists (where an externality is present).

[7] Further reading on valuing the environment and the costs of pollution can be found in Varian (1987), Titenberg (1992), Stavins and Whitehead (1992), Pigou (1932), Munasinghe (1993, 1995), Loeham and Conner (1974) and Kneese and Schultze (1978).

By charging producers of pollution a fee or tax on the amount of pollution they generate, the government provides them with an incentive to reduce pollution up to the point at which their marginal costs of control are equal to their pollution tax rates. Each economic agent (a firm or individual) will abate to different levels based on their marginal control costs. An effective system minimizes the aggregate costs of pollution control and enables the public to pursue higher levels of environmental quality than might have been affordable under less efficient command-and-control approaches (Stavins and Whitehead, 1992).

Perhaps the most important feature of an appropriate pricing mechanism (especially for an effluent or emission tax or an input tax) is the powerful incentive it gives firms to develop improved control technologies. It encourages pollution prevention as a means of reducing their tax bill. If less pollution is created, less is paid. In the case of a tax on industry all firms in the industry face the same situation, and those firms that can produce cleaner and more efficiently have a competitive advantage. A price based incentive internalizes the externality by making it profitable to reduce pollution, thereby making it profitable to seek "cleaner" production, activities or products.

When designing a price based incentive mechanism, the following policy effects should be taken into account (Anderson):

- **Economic Efficiency and Innovation:** An initial aim of environmental taxes is to raise the price of pollution or environmentally damaging products and practices such that the external costs to other parties, both present and future, are reflected in the price. The higher prices act to regulate the level of pollution or the damage to an asset. They also raise public revenue and private financial resources for the further reduction of pollution or for the maintenance of an asset.[8]

- **Innovation and Substitution:** Once taxes or regulations are implemented, products and practices change. Three types of changes may occur:
  - *Quantitative effects* - arising from demand and supply reductions.
  - *Substitution effects* - towards less polluting or damaging products or practices.
  - *Innovation* - in the direction of less polluting or damaging products or methods of production.

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[8] Prices before the implementation of a tax reflect the firms marginal cost (MC) of production, and the taxes are chosen to reflect the Marginal External Costs (MEC) imposed on other parties. After the imposition of a tax, prices rise to $P = MC + \text{Env Tax} = MEC$, and the use of the offending product or practice declines.

Under appropriate incentives, innovations and substitutions which reduce environmental damage are the rule--not the exception. They can lead to greater pollution reductions than taxes or regulations alone.[9]

Price based incentive mechanisms have several institutional advantages over a CAC approach in terms of cost and feasibility. Environmental taxes on commercial energy, fertilizers and agro-chemicals could be grafted onto existing taxes on those commodities. Taxes have long been a favored form of taxation in industrializing countries because of their administrative convenience. For many problem areas environmental taxes would work through existing administrative arrangements and would be operationally feasible. The tax approach is theoretically better than the CAC alternatives in terms of:

- efficiency
- administrative convenience and feasibility
- information intensivity
- revenue raising
- rent seeking.

The magnitude of the difference in costs between the two approaches depends on both the absolute and relative levels of the marginal cost curves. If marginal abatement costs are low, so is the absolute magnitude of potential savings. If the curves are very similar across pollution sources, the potential for cost savings is small. The savings become greater as the discrepancy between the marginal costs increases (Vincent, 1995).

An input tax is levied against harmful productive inputs. The tax is not linked directly to pollution levels. The tax is useful in situations where there is a strong link between an input in a production process and environmental degradation. It is a powerful incentive to induce pollution prevention because it is aimed at reducing the use of a harmful input instead of treating a problem that has already been created.

A product charge is most useful in cases where there already is a regulatory system in place to collect taxes. In areas where taxes are applied to consumer goods, product charges can easily be applied. These charges are directly linked to a harmful product and raise the cost of the product, thereby making it less affordable.

Price based incentive mechanisms can be applied to consumers or producers. For example, input taxes and emission/effluent charges are directed towards producers while product charges and user fees also have applications for consumers. All price incentive mechanisms are aimed at increasing the marginal cost of using the product, practice, resource or input to be inclusive of the marginal social cost.

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[9] Regulation forces $P = MC + M\overset{E}{U}C$ by reductions in quantity produced or the installation of new control technology. It may, or may not, achieve the greatest reduction in pollutants, but will still force prices to rise to the marginal external cost.

3.4 THE APPLICATION OF PRICE INCENTIVE MECHANISMS

The available evidence suggests that price incentives that are in use throughout the world today tend to be set too low to provide sufficient incentive for firms and individuals to significantly change their behavior. Often, firms and individuals prefer to pay the charge because it is more cost effective than abatement. Many of the incentive mechanisms that have been used were primarily designed not as incentives to reduce pollution or change production processes but to raise revenue for the government. In the few cases where the main objective of the policy was as a true "incentive" mechanism, they have proven to be highly effective. Those economic incentive mechanisms that have be applied in industrializing countries have also been hampered by market distortions that at best limit their impact and worse, can have detrimental environmental impacts.

3.4.1 User Fees

User fees are imposed on the use of a resource. They attempt to raise the price in order to reduce demand. The higher price of the resource encourages more efficient use.

Deforestation

Indonesia. Indonesia implemented a flat tax of $4 per cubic meter on forest products in an attempt to extract more rent from the clearing of forest reserves.[10] They then raised it to $10 per cubic meter in 1990 (ADB, 1994). In response to this tax increase, harvesters began "high-grading," or extracting only trees with high market prices while mangling and destroying lower value trees in the process. The low value trees were made too expensive relative to their market value by the tax, so they were left unharvested. The raising of the flat tax rate on trees only increased environmental damage, without increasing revenues or rent extraction. Trees that could be sold for profit were destroyed and left uncollected in the forest because the tax made it economically inefficient to harvest them.

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[10] Rent refers to the amount of economic value gained from an activity, including all benefits that accrue to all parties involved (i.e. profits to the forester and revenues generated by taxes, incomes earned etc.). Increasing rents implies greater economic efficiency. It is the goal of economic agents to gain as much rent from any action as possible. When an agent is profit maximizing, maximum rents are being created. This is the most efficient position available in that market.

Sarawak. In contrast, Sarawak levies differentiated tax rates based on the market value of the trees (ADB, 1994). High value trees are charged at a greater rate than low value ones. This ensures that all the trees from a given concession are harvested, increasing the amount of rent captured from the forest. This leads to a more efficient use of the natural resource.

Sabah. Sabah implemented a tax of $8 per cubic meter of wood. While this policy led to a closure of 1/3 of their 200 sawmills, it generated tax revenue that could be used as compensation. Sabah has been the most successful at capturing rents from forest reserves (logging activities). Their aggressive tax policy pegs royalties to world prices, and as a result they collect sixty to eighty percent of this rent (ADB, 1994).

Philippines. The Philippines has raised forest charges to $10 per cubic meter, and combined the charge with a reforestation deposit (ADB, 1994). This should increase the costs of forest use, which should reduce the incentive to enter the market.

Fish Reserves

Pacific Region. The South Pacific Fishery Forum Agency (FFA) negotiated a lump sum access fee applied to foreign fishing fleets. In 1988, the United States paid over $49 million in rent taxes to Pacific island parties. While the user fee applied to the fishing industry may have lead to high grading of fish reserves (increasing catch value by discarding the lower value catch back to the sea), the FFA monitored the fleets by sending observers on 20% of all trips (done by American fleets). The US industry agreed to meet the cost of the observer program as part of the 1988 treaty. The FFA calculated its total annual access fees were only about 3% ($30 million) of the total value of the fishing industry (ADB, 1994).

Cooperation between countries who share a resource to restrict access to common property resources is one way to address the problems of property rights and lost rents. The user fee also generates revenues which can be applied to administrative costs or other environmental problems which are not self financing. A lump sum access fee (a type of user fee) can lead to over fishing of the resource if not carefully monitored. While it does provide increased rent capture for the government(s) collecting the fee, it also provides financial incentive to continue fishing to maximize profits and recoup the fees by increasing catch size (ADB, 1994).

West Indian Ocean. The West Indian Ocean Tuna Association is based on the FFA program. This association, representing Camoros, India, Kenya, Madagascar, Maldives, Mauritius, Mozambique, Seychelles, and Sri Lanka, helps to integrate user fees and enforcement efforts for tuna (ADB, 1994).

Mining and Mineral Extraction

Pacific Region. User fees have been used to extract rents from mineral resources for many years. Clear property rights and careful management of mining resources has allowed some countries in the region to extract up to 80% of the rent from extraction (when compared to an average of 15-30% for forest reserves). This impressive result can be attributed to the relative administrative ease with which fees could be levied against a small number of large firms. However, in recent years regulators have lowered fees in an attempt to attract foreign investment. This has lowered the percent of rent capture per ton of minerals extracted (ADB, 1994).

Exhibit 1: Mining Taxes in Selected Asian Countries

Country	Royalty	Corporate Income Tax	Equity Participation
Indonesia	A royalty based on sales minerals. For coal, 13.5% of production is paid.	Rp 0-10 million: 15% Rp 10-50 million: 25% Rp 50+ million: 35%	-
Malaysia	-	35%	-
Papua New Guinea	1.25%	35%. Petroleum companies 50%.	10-30%
Philippines	Coal: not less than 0.2 peso/ton. Nonmetallic minerals 3% based over actual market value. Metallic minerals: 5% based over actual market value.	35%	-
Thailand	Sliding rate between 0-60% for tin and zinc. Flat rate of 2-20% for all other minerals.	30%	-

Source: ADB, 1994.

Air Pollution - Urban Congestion

Africa. In an African country the potential for large financial costs stemming from the overloading of trucks led a donor agency to attach the implementation of truck weight limitations as a restriction on financial aid. Although this policy was aimed at reducing road maintenance and construction costs, it had important environmental impacts because truck size, loading, and condition affect the proper operation of trucks and their emissions.

To enforce these restrictions, the United Kingdom provided a number of mobile weigh bridges. The weigh bridges were easily operated by people without technical knowledge; they were mobile so they were not easily avoidable by trucks making detours around known control points; they were accurate and reliable; and they could produce on the spot incontrovertible evidence that would stand up in court. It was an adaptable user charge system, allowing authorities to collect on site fines or to enforce higher penalties through the courts. This is a classic example of the "polluter pays" principle in which fees were assessed on those most responsible for the external costs. Unfortunately, this incentive mechanism was undermined by the fact that a large percent of the owners of overloaded truck fleets were senior government officials who were able to circumvent these fees.

Solid Waste

United States. In the state of Washington, King county uses a combination of tipping fees, variable rates for the quantity of waste collected (measured in the number of filled trash cans) and strives to build markets for recycled materials. Tipping fees are paid for waste disposal to the landfill and have increased by fourfold since the 1980s; these are intended to help cover the costs of cleaning up the landfills and complying with new regulations. The rates assessed for garbage pick up increase sharply for more than one trash can. It encourages residents to limit their trash pick up to one can per collection period. The rate increases approximately 40% from one can to two. The state of Washington also created a Commission for the creation of markets for recycled goods and engages in extensive education programs. In 1987, 18.3% of the waste stream was being recycled and by 1992, this figure jumped to 35%, indicating that the comprehensive program was successful in reducing the quantity of waste needing to be land filled (NAPA, 1994).

3.4.2 Effluent/Emission Charges

Emission and effluent charges are used to encourage the control of air emissions, wastewater discharges, and noise. They have generally been applied to wastewater discharges more than air emissions because it is often easier to identify and monitor wastewater discharge points. Australia, Belgium, the Netherlands and the U.S. all apply charges on municipal and industrial wastes. These charges can target the overall quantity of pollution in a given area and provide incentives for firms to reduce pollution levels to the target level or below. While effluent charges can achieve the same total level of pollution reduction as effluent standards, they equalize the marginal control costs among firms. Additionally, they encourage firms to find cheaper and more efficient ways of reducing pollution levels by providing a profit incentive for being "cleaner." This results in a cost-effective outcome in which fewer economic resources are used to achieve the same level of pollution control.[11] While these charges can be designed to provide incentives to reduce pollution levels, many countries use these charges primarily to generate revenue rather then to have a deterrent effect.

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[11] An excellent exposition on the economic efficiency issues presented here can be found in, *Environmental and Natural Resource Economics*, by Tom Titenberg 1992.
Pg 360-380.

Water Pollution - Industrial

Effluent charges are perhaps the most widely used economic incentive mechanism. Malaysia, France and Germany are noted for their early and effective use of effluent charges.

Czechoslovakia and Italy. These countries use dual effluent charge which combines a permit and base licencing fee with a variable fee based on the quantity of effluent discharged. This type of hybrid economic incentive and CAC system is popular with governments because they ensure a certain level of revenue generation. Italy's program was designed to encourage the polluters to achieve effluent standards as soon as possible (Titenberg, 1988).

Netherlands. The Netherlands employs a fee system that varies the fees based on quantity of discharge, concentration of pollutants, and the location of discharge. Higher fees are paid depending on the environmental damages presumed to occur based on the chemical constituents in the effluent. Charges are collected in conjunction with the electric bill of each firm. The results of this system indicate a 90 percent reduction in pollution in 15 years, and over $300 million in revenue has been collected (Hagler Bailly, 1994).

France. France implements discharge fees in each of its six major river basins according to the concentration of pollutants, flow and location. Total fees are capped at 2.5% of value added at each industrial location. Fee rates are adjusted annually to recover the full cost of administering water pollution control programs within each of the six river basin authorities (Hagler Bailly, 1994).

Germany. Germany collects industrial effluent fees based on flow, pollutant concentrations and toxicity of discharges to local fish populations. Fee rates are set just above pollution control costs to encourage dischargers to reduce the quantity of discharge. Fees are reduced by half if CAC limits are met. More than half of German industry meet the standards. Revenues are used to finance water pollution control programs (Brown and Johnson, 1984).

United States. In the United States, 35 out of 50 states impose industrial effluent fees. Most regulatory agencies seek to recover 50% of the costs of their water pollution regulatory programs. The state of New Jersey is an exception in that its effluent charge system is based on quality, location and concentration of discharges. Its collected fees recover the entire cost of its regulatory program (EPA, 1991).

Thailand. To address major sources of industrial pollution, Thailand has used a combination of effluent charges and user fees. The first central wastewater treatment facility for industrial waste in Thailand was set up on the Mae Long river which was highly polluted by sugar mills. It was financed by charges levied on industrial users. In 1988, the Bang Khuntien Treatment Center was set up by the Ministry of Industry to deal with heavy metal contaminated wastewater. As of 1990, it has treated 8,300 tons of hazardous waste (ADB, 1994). The private company responsible for running it recovers its operating costs by levying a waste treatment fee on all factories which use it. The fees vary with the type and quantity of waste to be treated and the distance over which it must be transported. In addition, as an incentive for firms to use the facility the government assesses a fixed charge of 70% of treatment costs for each company's waste, irrespective of whether it uses the facility. This dual charge system ensures that firms have an incentive to use the facility as well reduce emissions (OECDa, 1992).

3.4.3 Product Charges

Product charges are based upon the potential pollution of a product. They are not linked directly to the level of pollution created, but on the long-term environmental problems created by the use of the product. Product charges function like effluent charges in that they allow users to determine the most cost-effective means for reducing the use of polluting products. They allow for a market allocation, which should reduce use of the harmful product or practice.

Soil Erosion/Conservation

Netherlands. The Dutch Manure Surplus charge appears to be an effective pollution-control incentive. The charge is based on the phosphate content of manure above and beyond the amount farmers are allowed to put on their land (OECDa, 1992). The taxing of fertilizers above a stipulated quantity provides an incentive to farmers to reduce the use of fertilizers. The imposition of a tax creates a higher price which reduces the use of fertilizer. When too much fertilizer is applied to crops the excess runs off and can create water pollution problems (increased nitrogen and phosphate levels in downstream water bodies) and health hazards.

This charge is easily applied, and requires little administrative information. The regulator does not need to know who the individual farmers are who apply too much fertilizer, since it is applied directly to the product when it is purchased and collected by the retailer who sends it to the appropriate agency. The surplus charge incorporates market forces by increasing the price of fertilizer, and thereby achieves pollution reduction without direct governmental control of fertilizers. It leaves the decisions about how much fertilizer to use to the individual farmer.

Solid Waste

Norway and Sweden. These countries apply product charges to batteries, fertilizers and pesticides (OECDa, 1992). The product charge raises the price of the harmful product, which can make it less desirable and reduces its use. Since these charges are assessed on the product itself, they are less information intensive than comprehensive CAC regulations on the producer of the harmful product. Production of the harmful product will be reduced if the price was high enough to reduce demand by a large enough proportion.

Italy. Italy levies a tax on plastic bags which is paid by manufacturers and importers (OECDa, 1992). By assessing the fee on manufacturers and importers, who in turn raise the prices to consumers, demand for plastic bags is reduced. This is an attempt to encourage conservation, reuse and substitution of plastic for a more environmentally friendly way to package consumer goods. This tax is easy to collect and administer since the number of suppliers of plastic bags is far less than the number of consumers and users.

Hazardous Wastes

Germany. Germany applies a product charge to lubricant oils. The amount of improperly disposed waste oil dropped to 5,000 tons per year in 1989 (a decrease from 92,000 tons in 1979).

Italy. Italy employs a product charge on lubricant oils. Waste oils collected increased from 55,000 tons in 1985 to 105,000 tons in 1986 (OECDa, 1992).

3.4.4 Input Taxes

Input taxes are linked to environmental degradation, but not to the amount of pollution created by a product. They attempt to increase the price of harmful inputs in order to encourage firms to decrease their use and engage in input substitution. By increasing the price of one input relative to another, a profit maximizer will chose the least-cost alternative. These taxes make the cleaner alternative the least-cost alternative.

Green House Gas Emissions

India, Indonesia, Japan and Pakistan. These countries have employed a carbon tax which has had significant environmental impacts. A carbon tax is an input tax because it is a fee levied against the amount of carbon contained in coal, which is an input in many production processes (e.g. power generation). Exhibit 2 shows the reduction in sulfur oxides, nitrogen oxides and particulate emissions.

Exhibit 2: Reductions of SOx, NOx and Particulate Matter (PM) caused by a $10/ton Carbon Tax, 1987

Emissions	India	Reduction %	Indonesia	Reduction %	Japan	Reduction %	Pakistan	Reduction %
SOx	2,207	15.9	337	4.6	1,600	2.3	321	19.1
NOx	2,090	11.9	434	3.8	1,400	1.2	203	3.8
PM	1,192	15.3	87	5.0	463	0.6	44	11.6

Source: ADB, 1994 * in tons per year

3.4.5 Deposit/refund Systems

Deposit/refund systems can range from administratively complex to simple. If the deposit/refund is applied to products contributing to hazardous waste problems (like lead-acid batteries, containers for pesticides etc.) then more monitoring and enforcement administration is needed. In the case of mining and forestry deposit/refunds, the system can be attached to existing permit or concession systems. In the case of beverage containers, making it the responsibility of the retailer (as in the Michigan experience) should result in high rates of return with nearly non-existent administrative costs.

Solid Waste - Municipal and Industrial

Korea. Korea has introduced a deposit/refund system for a number of products which contribute to waste disposal problems. They include food and beverage containers, pesticide containers, batteries, tires, lubricant oil and plastics. As of mid 1992, the deposits paid totaled $16.9 million while refunds amounted only to $38,000. This suggests the system provides little incentive to recover waste products. This can be attributed to the low deposit/refund fee. Taiwan has also begun to implement a recovery system for 12 types of solid waste, including used tires, aluminum cans, waste paper, etc. Details on the effectiveness of this system are not yet available (OECDa, 1992).

India, Syria, Lebanon, Egypt and Cyprus. Throughout these countries, deposit/refund systems for beverage containers are widespread, and all have deposit/refund schemes for carbonated beverage containers made from glass.

Australia, Canada, France, Germany, Switzerland and the U.S. These countries all have adopted deposit/refund schemes for specific kinds of beverage containers (e.g., different grades of plastic, glass and aluminum). Denmark, Finland, Norway and Sweden are considering the implementation of similar systems for batteries with high mercury and cadmium content.

Norway. Norway has used a deposit/refund system for car hulks since 1978, resulting in 90-95% of car hulks being returned in Norway (OECDa, 1992).

United States. The U.S. has a wide range of experience with deposit/refund systems. The state of Oregon has had a mandatory deposit on soft drink and beer containers since 1972. The states of California, Connecticut, Delaware, Iowa, Maine, Massachusetts, Michigan, New York and Vermont all have beverage container deposit schemes in place. Oregon reported a reduction in all roadside litter of 75-85% just two years the implementation of a deposit/refund system. The state of Rhode Island provides a mandatory deposit on all automobile batteries. Starting in 1989, every battery sold was required to have a $5.00 deposit paid at the time of sale. The payment of the deposit was waived if a used battery was traded in at the time of purchase. The state of Massachusetts has implemented a program that charges a deposit $0.50 per quart of oil purchased, which is refunded if the customer brings back used oil when purchasing new oil. This policy was aimed at reducing the amount of waste oil illegally disposed of by do-it-yourselfers (API, 1990).

An extensive study of the Michigan experience shows the net effect of the 1978 "Bottle Bill" to be positive. Although the Michigan deposit was 10 cents per bottle, it seems that deposits as low as 2-5 cents per bottle will induce significant return of beverage containers. Roadside litter decreased by as much as 85% as a result of the mandatory deposit, and the quantity of littered containers fell from 153.2 to 19.3 million per year.[12] It is estimated that the deposit reduced the per mile clean up cost by 13.2%. When multiplied by the total road mileage in Michigan and compensating for the differences in municipal and rural clean up costs, savings are estimated at around $4 million. If the cost of solid waste disposal is $30 -50 per ton (in 1979 dollars) and a 6.0% reduction in solid waste occurred (7 million tons of solid waste generated per year), then the "Bottle Bill" lead to a reduction of around $18 million in solid waste costs.

Mining

Malaysia. Malaysia uses deposit/refunds to rehabilitate mined areas. Deposits range from M$1,000/acre in Johore to M$5,000/acre in Kuala Lumpur and Selangor.

Deforestation

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[12] Another study showed the reduction to be from 316.4 to 48.8 million containers by M.D.O.T (Michigan Department of Transportation in 1979.

Indonesia. In the 1980s, Indonesia levied a forestry deposit fee on loggers which would be refunded upon the replanting of a logged concession. Similar to the other deposit schemes above, the fee was simply treated as an additional cost. The per hectare fee was a small fraction of the actual costs of replanting, so the logger had no incentive to replant. Even a doubling of the fee was not expected to create an incentive effect (ADB, 1994).

Philippines. The Philippines has raised forest charges to $10 per cubic meter combined with a reforestation deposit (ADB, 1994). This has proven to be a fairly successful system, as it provides funds to rehabilitate degraded areas, whether or not the refund has been collected.

3.4.6 Tax Differentials

Tax differentials are designed to encourage the use of one input or good over another by charging a higher tax on one product and a lower tax (sometimes a rebate) on an environmentally friendly good. These are most often used for different fuel types because the legal and administrative framework already exists. Tax differentials are easily integrated with existing taxes. See Section 3.9.2.

3.5 LESSONS FROM THE APPLICATION OF PRICE BASED INCENTIVES MECHANISMS

The experience of both industrialized and industrializing countries in using price based incentive mechanisms has shown that successful implementation depends upon several conditions. Key conditions include the following (Heaton, Repetto and Sobin, 1990):

- The agency responsible for environmental policy must have sufficient technical knowledge to formulate and implement economic incentives, and polluters must have the knowledge needed to respond appropriately.

- The legal structure must adequately define property rights and establish the authority to implement and enforce incentive systems.

- A country must have a competitive market that is relatively free of market distortions. Prices and competition must play a meaningful role in a nation's economic structure and in the decisions of those responsible for pollution.

- The responsible government agency must have the financial and administrative capacity to initiate, monitor and enforce incentive programs.

- The application of economic incentives must gain the acceptance of the government, the community of polluters and those affected by pollution.

While these conditions are important for all countries, certain conditions exist in many industrializing countries that could limit the application of price incentive mechanisms. For example, securing and enforcing exclusive property rights is a significant problem in many countries especially those in which cultural traditions are based on communal access rights to fishing, grazing and forests. In areas that have communal property rights, individuals tend not to have the incentive to conserve resources or reduce pollution.

Another problem in many industrializing countries is the governmental control of, and access to, resources both natural resources and productive resources. As the owners of these resources, a government typically does not respond to price incentives. This is true for countries that have state owned enterprises. Typically, state owned enterprises and firms are not strongly bound to market signals; therefore, plant managers have little incentive to minimize costs, as profits may not accrue solely to the facility in question. Economic instruments are most effective where firms are sensitive to changes in price because they are in competitive markets and are constrained by profit maximization (cost minimization). The Eastern European experience with pollution charges shows that in conditions where such charges have little influence on the objectives of managers (who may be only loosely committed to cost control and profit maximization), a price incentive mechanism is likely to fail.

3.6 QUANTITY BASED APPROACHES

Quantity based approaches attempt to create a market for "goods" that are currently outside the market system. When property rights are extended to the externalities, they can be traded as any other property or commodity. Tradeable permits are the most common form of a market creation mechanism. A tradeable permit scheme works by setting the maximum amount of pollutants allowed, as in a traditional CAC approach, but then allows firms to "buy" units of pollution. There is an initial allocation of permits which specify the type and quantity of pollution allowed to be discharged. This creates a finite amount of pollution, which then creates "scarcity rent" for the "good." Each source is allocated a portion of the total amount of pollution which is usually based on existing ambient quality standards. Under this system, firms with low abatement costs would are encouraged to adjust their processes in order to take advantage of being able to sell excess pollution rights to firms with higher abatement costs (EPA, 1991).

Under a tradeable permit program established under the Clean Air Act in the U.S., any source that reduces discharges more than is required by the standard can apply to the control authority for an emission reduction credit (Bernstein, 1993). The emissions reduction credit (ERC), defined in terms of a specific amount of a particular pollutant, can be used to satisfy emission standards at other discharge points controlled by the same source, or it can be sold to other sources. The ERCs may be applied internally through netting, bubbling or offsetting. They also may be banked for future use or sale. This provides an incentive for firms to reduce pollution discharges so they can sell excess permits, and avoid the cost of having to purchase additional units of pollution. The permit system works by extending property rights to pollution, thereby engaging traditional market forces.

- **Bubbles.** The name derives from the placing of an imaginary "bubble" over a plant, with all emissions exiting at a single point from the bubble. It allows a plant to sum the emissions from all sources within the plant and adjust the levels of control applied to different sources as long as the aggregate limit is not exceeded. The managers of the plant have the flexibility to select a set of controls to achieve the limit, rather than having to conform to specified treatment procedures for each source of discharge within the plant (Journal of Law and Economics, 1995). In theory, a bubble can be used for more than one plant or firm, thus involving external trading.

- **Netting.** In netting firms can avoid stringent emissions limitations on new sources of discharges by reducing emissions from other sources of the pollutant within the plant. Thus, net emissions would not increase significantly. A firm using netting is allowed to obtain the necessary ERCs only from its own sources.

- **Offsets.** Offsets involve internal or external trades in "nonattainment areas." Under this system, new sources can locate in nonattainment areas as long as they offset their new emissions with larger reductions by acquiring ERCs from existing sources. Offsets allow for external trading.

- **Banking.** Banking allows firms to store ERCs when they exert greater control over emission than is required by the existing technology standards.

Tradeable permit schemes can be applied to air and water pollution, as well as to a myriad of other environmental concerns Most countries have used tradeable permits to address air pollution concerns. Permit schemes attempt to create a market for pollution by assigning property rights.

In a market where there are a significantly large number of firms engaged in polluting activities, discharge reductions can be obtained by creating a market for the pollution and allocating the number of permits at a level slightly lower than current levels. For example allocations could be made at 90% of current levels. The regulator could also design the system to incrementally decrease allocation levels over time. This would minimize the economic impacts by giving industry a sufficient quantity of time to invest in cleaner production technologies and processes.

3.7 APPLICATION OF QUANTITY BASED APPROACHES

3.7.1 Tradeable Permit Systems

For permits to serve their purpose as incentives for behavioral changes, total emissions levels must be set so that emission permits are relatively scarce. Scarcity makes the permits valuable to polluting firms, creating incentives to trade pollution among firms. Marketable permits shift decisions about the design and location of pollution control equipment form government agencies to plant operators who have greater information about their plants' operations than public officials. Available evidence shows unit abatement costs are lower with permits than with regulation. However, the evidence is ambiguous as to whether permit systems provide greater stimulus for innovation in pollution control technology than regulatory systems.

Air Pollution - Industrial and Green House Gas Emissions

United States. The United States has the most extensive experience with emissions trading programs and tradeable permits systems. The EPA's Emissions Reduction Credit Program is designed to encourage compliance with the 1990 Clean Air Act. The United States' emissions reduction program operates nationwide and covers most of the significant stationary pollution sources. The program attempts to reduce emissions that cause acid rain and other deleterious environmental and health effects. The five main air pollutants covered are: hydrocarbons (ROG), nitrogen oxides (NO_x), particulate matter (PM), sulfur oxides (So_x) and carbon monoxide (CO). The tradeable commodity is the emissions reduction credit (ERC). Credits can be created by reducing sources of pollution elsewhere, either within the same plant, firm or industry (Journal of Law and Economics, 1995).

The net amount of pollution allowed is the same under a permit scheme as is set by a CAC standard; however, it is the allocation of the right to discharge that is variable. Over 200 trades involving over 100 firms have occurred since the implementation of the program. Ten thousand tons of pollutants have been traded, at a total value of $2 billion. Transaction costs and the effect of regulations on the banking behavior of firms are key elements of the program. An important finding in the U.S. ERC experience is the magnitude of transactions costs and their effect on the incentive to engage in external trades (trades between firms). In many instances, the burdensome monitoring and regulations governing trade were prohibitive, and transaction costs exceeded the value of the credits traded (Journal of Law and Economics, 1995).

Emissions trading can save large sums (up to 90 percent of control costs according to a 1982 GAO study) of money. However the actual number of emissions trading that took place in the U.S. represents a small portion of all air emissions. According to the American Petroleum Institute (1990) savings from trading (when estimated at face value of the traded permit) are at the most $5.5 to $12.5 billion, an approximate 2 to 4 percent of total air pollution control expenditures.

Poland. Poland is considering an emissions trading program loosely based on the U.S. program. Some have noted that many of the problems with the U.S. system are regulatory in nature and not intrinsic to the trading permit scheme.[13] The most important problems may be less serious with a wider trading scale, and many resulted from the limited market structure. With a greater number of firms the full effects of substitution and innovation (i.e., pollution prevention) should be achieved by the incentive.

In Poland a limited trading scheme was implemented in Chorzow, a city in Upper Silesia, in 1992. In Chorzow, there was significant pollution from two plants. A steel mill and a power plant. The steel plant had already invested in equipment to reduce emissions, such as closing coke ovens and piping in natural gas. The power plant, however, is outdated and out of compliance. It considered modernizing its fluidized bed boilers, but the capital expenditure was prohibitive. As reducing output is not a viable solution for reducing pollution, its only alternative is to invest in control technology. To take advantage of the steel mill's lower abatement costs and more modern facilities, regulators engaged in a limited trading scheme between the two firms in order to minimize the total abatement costs. However, this plan was never fully implemented because it lacked the full support of local officials. Poland also experimented with a coal tax that was ineffectual. The results showed that pollution control policies need to be broad-based to reduce emissions at a reasonable cost. Focusing on a limited number of fuels or sources is likely to be ineffectual and expensive (Bates et al, 1994).

Hazardous Wastes, Industrial Air Pollution

United States. One of the earliest trading programs in the U.S. was a program for phasing lead out of gasoline. The EPA mandated a quarterly average for the lead content in gasoline. Refiners and importers were allowed to sell lead use rights so longs as their individual average lead concentrations did not exceed the limit. The lead trading program created clearly defined property rights to refiners and importers of gasoline. This created a market with hundreds of participants. Lead rights were traded in the range of three fourths of one cent to over 4 cents per gram of lead. The existence of trades implies that there were efficiency gains due to the lead trading program. EPA estimated just over 10 billion grams of lead were banked, which had the potential of saving refiners $226 million. This represents an average savings of 2.5 cents per gram of lead banked (API, 1990). This implies a net reduction in the lead content of gasoline without costly mandates.

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[13] Regulatory difficulties in the US case include: monitoring, verifying trades, guarding against market power, and reconciling emission controls with ambient air conditions.

Fish Reserves

Australia and New Zealand. Individual transferable quotas (ITQs) are assigned to fisherman according to their historic catch or by auction. They are allowed to trade the ITQs. The most efficient fishermen can buy extra quotas while inefficient fisherman can sell them and be compensated for relinquishing their fishing rights. In Australia the number of fishing vessels fell from 136 in 1984 to 63 in 1987. As a result of the trading scheme, the value of each ton of fish caught has increased five fold from the harvest of more mature fish.

Bangladesh. In Bangladesh, the jilmahals (traditional fishing rights) were leased on a yearly basis to the highest bidder. However, this failed to reduce rent dissipation and open access fishing since the licensees were non-fishing middlemen who then collected tolls that were up to 33% of the value of the catch. The middlemen rigged the auction to keep prices down and allowed as many fishermen as possible to fish, drastically reducing the average income to the fishermen. This policy was changed in 1987 so that only fishermen could buy leases (ADB, 1994).

3.7.2 Auctions, Actionable Permit Schemes and Concessions

When the government wants to limit the use of an environmental good (or product that has a potentially damaging impact), it can allocate the "rights" to that good through auctions or concessions. When demand is high, the price at which the good can be sold is increased, thereby increasing its overall value to the producer or consumer.

Ozone Depletion

Singapore. Singapore has implemented a system of actionable permits for the consumption of ozone depleting substances (ODS). Each fiscal quarter the national quota of ODS is allocated among importers and users of ODS. Half the allocation is given on the basis of historic consumption and half through an auction. Importers and users must register to participate in a process, conducted by sealed bid, in which each firm indicates the amount of ODS it would like to purchase and its offer price. Bids are ranked by price, and the lowest winning bid (the one which clears the market) serves as the quota price for the full allotment f ODS. This quota price is also the fee charged for the 50 % historical use allotment. In ingapore there are sufficient numbers of bidders to establish competitive market conditions. The rapid increase in quota prices during the first few rounds of bidding, well before firms ad made serious efforts at conservation and substitution, provides evidence of a price sensitive market. The auction allows the government to collect a large portion of the quota rents, which are then used to subsidize recycling services and the diffusion of alternative cleaner production technologies (OECDa, 1992).

Deforestation

Sarawak. Sarawak used sealed tender auctions to sell forestry concessions. Almost 40% of the total forestry concession has been disposed of by these sealed auction bids. Prices range from M$0.2 to M$0.3 per ha.(ADB, 1994).

Air Pollution - Nonpoint and Urban Congestion

Singapore. In 1976, Singapore implemented the Area Licensing Scheme which requires a permit for cars to enter the city during the morning rush hour. The permits cost around $3 a day or $50 a month. Company cars are charged double. This has resulted in a 75% decrease in the number of vehicles during rush hour and a 20% increase in bus commuters, a 50% increase in car pooling and substantial reductions in downtown air pollution (ADB, 1994).

3.8 LESSONS FROM THE APPLICATION OF QUANTITY BASED APPROACHES

Overall, the experience with tradeable permits has proven to be cumbersome. Their application, especially in the U.S., has been hindered by lengthy litigation, argument about baseline levels and the need for governmental approval at all steps (OECDa, 1992). In addition to the elements highlighted in Section 3.5 for the successful use of price based incentives, the key elements needed for the implementation of a permit trading scheme and quantity based approaches are:

- **Enforceable Property Rights.** Firms responsible for pollution must be held accountable for pollution. The permit must specify the type and quantity of pollution the firm now owns. The property rights must be exchangeable. The profits or losses from sale must accrue solely to the owner of the permit.

- **Competition.** A significantly large number of firms must be willing to participate in trading, and that those firms respond to price signals from the market. Firms must be profit seekers.

The creation of markets entails the extension of property rights to pollution in order to create a basis for trade. Once property rights have been extended to the production of pollution, firms will respond to price signals. This provides firms with incentives to reduce pollution through the use of cleaner production technology and other abatement actions. Tradeable permits are one of the most extensively used market incentives, and can be successfully implemented in industrializing countries. However, if the system is improperly designed it can lead to unduly expensive transaction costs in its implementation.

3.9 OTHER TYPES OF ECONOMIC INCENTIVES

When defined broadly, economic incentives can include a host of other types of policies that provide some incentives to individuals and firms to improve their environmental practices. These measures are generally used with command-and-control regulations as a means to improve their effectiveness.

3.9.1 Tax Incentives

Tax incentives include tax breaks, subsidies and transfer payments for cleaner production, processes or practices. These are generally applied to industry and firms to encourage them to switch to less damaging practices.

Inefficient Production Practices

Thailand. The Ministry of Finance in Thailand discounts the standard tariff on imported end-of-pipe waste treatment technology as an incentive for firms to invest in environmental improvements. By 1989, only $7 million worth of technology eligible for the reduced tariff had been imported. The incentive does not appear strong enough to induce higher investment levels. In an attempt to improve environmental quality the government is considering extending the tariff discount to clean process technologies. The quasi-governmental Industrial Finance Corporation of Thailand provides financing for pollution abatement technology, helping to alleviate investment fund deficiencies prevalent among small to medium size firms in industrializing countries (OECDa, 1992).

Indonesia. In Indonesia the Ministry of Population and Environment implemented an import tax reprieve for waste treatment equipment (OECDa, 1992).

Japan. The Japanese government offers a number of tax incentives for pollution control investments. These include accelerated depreciation schedules for pollution control facilities and for non-polluting processes. They also offer exemptions from the fixed asset and business taxes for investments in pollution control facilities (OECDa, 1992).

Deforestation

Sabah and Sarawak. Between 1990 and 1992, Japanese firms invested over $100 million in wood related business in Malaysia (ADB, 1994). Increased foreign investment can result in cleaner, more efficient production techniques that minimize raw material inputs and waste. Cleaner technology investments can eliminate the need for costly waste treatment procedures at the end of the production process. It can also lead to higher profits for the industry resulting from decreased input costs and higher product quality. The environmental ramifications of cleaner process technology investment are substantial.

3.9.2 Tax Differentials

Tax differentials attempt to influence behavior by taxing an environmentally damaging product at a higher rate than a cleaner alternative.

Hazardous Wastes - Air Pollution, Nonpoint

Thailand. The Thai government subsidizes the price of unleaded gasoline to make it competitive with leaded gasoline. The subsidy on unleaded gasoline is financed by a surtax on leaded gasoline. Unleaded gasoline was introduced in May 1991, at a discount rate of .30 baht (1.2 US cents) per liter relative to leaded gasoline. Currently unleaded gasoline accounts for roughly 25% of the market in Bangkok. As a result of the price differential, a thriving market for the refitting of lead to unleaded burning engines has developed. The price incentive is reinforced by regulation. After September 1 1993, all new cars sold were required to be equipped with catalytic converters. This has the beneficial side effect of increasing the demand for unleaded gasoline (OECDa, 1992).

3.9.3 Performance Bonds

Performance bonds are similar to a deposit/refund system. The deposit is paid to the government and returned upon satisfactory environmental performance.

Deforestation

Philippines. The Philippines uses a performance bond to encourage foresters to replant logged concessions. The bond is $400, but it costs over $500 to replant a hectare of forest. As a result, it is cheaper to forfeit the bond than replant the logged concessions (ADB, 1994).

3.9.4 Subsidies

Subsidies have been widely used throughout the world. In most cases subsidies work only to exacerbate environmental problems. They create distorted prices that result in the inefficient allocation of natural resources and create artificially low prices or spur excess supply of goods. When inappropriate price signals are involved the market will not operate effectively, thereby wasting valuable often nonrenewable environmental goods. The agricultural sectors of nearly all nations are heavily subsidized. Farm income supports and accompanying supply regulations encourage high input agricultural techniques that generate serious non-point solution problems (Heaton, Repetto and Sobin, 1990).

Agricultural, Soil Erosion and Energy

Pacific Region. Input subsidies create distorted prices which undermine environmental objectives. Pesticide subsidies in Indonesia, fertilizer subsidies in Korea, subsidized energy (lignite in Thailand, energy prices in Korea and Thailand), and low water charges (everywhere) are common examples of input subsidies that create serious environmental problems. Japan stands out as an example of a country where high market determined energy prices have acted as a major stimulus to energy saving technical innovation. In 1988, Japan had the lowest energy intensity (measured as TOE per US$ 1,000 of GDP) of any OECD country, 0.27 compared with an average of 0.41 (ADB, 1994).

Indonesia. Indonesia has recently reformed its pesticide subsidy policy. From 1976 to 1988 the government subsidized pesticides to the extent of 82 % of the retail price, encouraging heavy use by farmers and endangering the rice crop due to the decline in predator populations and the threat of a major brown plant hopper infestation. In 1988, the subsidies were reduced to 40% of retail prices. While the subsidy element is still significant, the reduction combined with a ban on 57 pesticides and the introduction of an integrated pest management system has helped avert disaster (ADB, 1994).

Deforestation

Pacific Region. Subsidies for forestry activities that often lead to price distortions are timber processing, log export bans, reduced export taxes on processed wood, cheap credit, tax break for domestic wood processors. These subsidies are intended to protect the value added of the domestic processing industry, but often they result in severe environmental degradation. The export ban creates a domestic glut of logs which result in a decline in price, lowering profits in the industry (ADB, 1994). Logs are sold at an artificially low price and rent is lost. An export ban also encourages smuggling as harvesters and processors seek to sell at the higher international price. When smuggling occurs the domestic economy gains little to no benefit from the harvest of its forest, but incurs all of the costs. The underpriced processed wood means that valuable rainforests are being cleared and the economic value is not extracted.

Indonesia, Malaysia, Philippines and New Guinea. The heavily subsidized domestic log processing industry in Indonesia and Malaysia has led to a glut of logs domestically, decreasing their value. The artificially low price of logs created by the subsidy and high rates of process inefficiency means the domestic timber processing industry has very low timber conversion rates and high costs. In Philippine mills, 30-50% of timber is lost during processing, compared to 15% in some industrialized countries. It is estimated that domestic timber processors in New Guinea lose K 100 per cubic meter of wood processed (ADB, 1994).

3.9.5 Voluntary Compliance Programs

Pollution control agreements between industry and government (or local communities) are employed widely in Japan and Indonesia and on a more limited scale in other countries.

Japan. In Japan, there are 33,000 pollution prevention agreements in effect (as of September 30, 1989). Between October 1988 and September 1989, over 2,670 agreements were concluded with 350 agreements in the metal and machinery industry and another 134 in the food processing industry. In 346 cases, the agreements involved some form of local citizen participation, with citizens reaching independent agreements with firms (i.e., without local government involvement) in 219 cases (OECDa, 1992).

Indonesia. The voluntary compliance programs are known as Prokasih are intended to clean up the most heavily polluted rivers. Originally, major pollution sources along the 20 dirtiest rivers were targeted, although the scope was later expanded to include other endangered water bodies. Firms with the largest pollution loads were asked to draw up pollution abatement plans which would form the basis of the agreements. The agreements are not legally binding but have been effective in deterring polluters because the government occasionally publicizes the names of firms not honoring their agreements. There have been significant improvements in BOD and COD loadings in a number of rivers during the first two years of its implementation (OECDa, 1992).[14]

United States. The U.S. has a vast array of voluntary compliance programs. One of the most noted is the Chemical Manufacturers Association's Responsible Care program. Even though it is a voluntary program it has been highly successful at inducing firms to implement pollution prevention and pollution abatement plans. The Chemical Manufacturers Association (CMA) is a nonprofit trade association whose approximately 175 member companies account for more than 90 percent of basic industrial chemical productive capacity in the United States and Canada. To join CMA a firm must implement the Responsible Care program. The association acts as an advocacy group for chemical manufacturers, as well as providing research services on chemical products. The CMA implemented Responsible Care in 1989 which has become the framework around which CMA member companies operate. The operating mandates in the Responsible Care program include pollution prevention and an obligation to participate.

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[14] BOD stands for biochemical oxygen demand and COD stands for chemical oxygen demand. These are water quality measures that describe the pollutive capacity of the effluent discharge. The higher the BOD or COD load the more volatile the waste.

The operational guidelines for the Responsible Care program attempt to create a comprehensive view of the chemical product, covering all aspects of the product cycle. The operational guidelines were developed to change managements view of chemical manufacture to include making environmental and safety concerns a top priority. The focus of Responsible Care is in pollution prevention and encourages firms to reduce the toxicity of their products and processes.

These principles and management practices attempt to cover all stages of a chemical's life-cycle. **Occidental Chemical Corporation** installed a new de-watering system to remove solids from tank car washwater. They reuse the cleaned wastewater elsewhere in their manufacturing process. The new system reduced wastewater discharges by 5 million gallons per year and reduced treatment sludge by 70 tons per year. They also installed equipment that recaptures chloromethane from the waste stream, completely eliminating the hazardous component from the waste. At another one of their facilities an ion exchange system reduces mercury in effluent by 99 percent. They also implemented a process change that recirculates wastewater from the manufacturing process for reuse by their mining operation, this resulted in a significant reduction in wastewater discharge as well as reducing the quantity of water required for the mining operation.

Amoco made significant reductions in discharges in response to CMA's program. They reduced air emissions by 38 percent within two years, cut solid and hazardous wastes by 45 percent and reduced the amount of wastewater discharged (and treated) by 50% per day. **Exxon** reduced emissions of two carcinogens, ethylene oxide and propylene oxide. They installed a cryogenic vent condenser system that recovers vapors from storage and weigh tank loading operations. This allowed the plant to reduce hazardous air pollutants by 90 percent.

The performance of the Pollution Prevention Code of Responsible Care is measured by EPA's Toxics Release Inventory.[15] CMA reports that member company toxic releases declined by 35% since 1988. Off-site transfers were reduced by 39 percent. The changes in production processes have resulted in cleaner, more efficient manufacture of chemicals and have substantially improved environmental quality.

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[15] The EPA's Toxics Release Program (TRI) is a compilation of the toxic releases and off-site transfers of 20,000 general manufacturing facilities. CMA member companies operate approximately 1400 of the reporting sites.

It is important to note that these improvements were accomplished without government intervention or regulation. The chemical industry responded to increasing public awareness of environmental degradation and the threat of costly government imposed regulation. Responsible Care was developed as a preventative measure against stricter standards. CMA felt it would be in the best interest of the industry to develop a comprehensive strategy that focused on emission reduction using cleaner production. Responsible Care attempts to view the entire life cycle of the product, insisting that chemical manufacturers be responsible for the product they produce from "birth to death." This provides industry with incentives to: create cleaner products; engage in input substitution; process change; and to invest in pollution control equipment.

The mandatory implementation of Responsible Care for CMA members provides a powerful tool for environmental quality improvement. In return, the CMA provides it members with a potent advocacy force in government. The advocacy aspect of CMA assures that industry and government work together to create least cost solutions to environmental problems.

4.0 CONCLUSION

Economic incentives attempt to modify producer and consumer behavior by using economic gains or losses instead of mandatory rules. An economic incentive is designed to encourage efficient behavior by changing the price signals perceived by individuals or firms rather than by mandating a specific course of action. Economic incentives incorporate the cost of environmental degradation into the production decisions of polluters and the consumption decisions of consumers. They work through markets to signal appropriate behavior. Three broad classes of market based incentives are:

- price based incentives
- quantity based approaches
- other economic incentives.

For the most part, these incentives mechanisms attempt to correct market failures and internalize externalities.

Rapidly industrializing countries have an opportunity to take advantage of the role these mechanisms can play. Countries with high rates of capital investment can provide incentives for the installation of the latest available process technologies, technologies that tend to be less polluting and energy intensive. As a consequence, in high investment countries, end-of-pipe solutions can be expected to play a diminished role as many problems can be addressed at the source with new plant and equipment purchases (OECDa, 1992).

It is important that the incentive program be flexible and allow for corrections, especially in the case of charges and fees which must be adjusted for inflation so that the incentive does not lose value over time. If the pressure of an economic incentive falls rather than rises over time, little change in behavior is accomplished and no incentive to invest in new technologies is created. Rates should be low in the beginning and increase gradually based on a predetermined and pre-announced formula. Lower initial charges that rise predictably are easier to get accepted and introduced. They allow time for adjustment, which minimizes resistance and cost, and it sends the correct signals to investors and innovators. An ideal economic incentive is incorporated into the price of a resource or product, and can only be avoided by avoiding the use of the resource or product (OECDa, 1992).

Shifting the tax burden away from socially desirable activities (such as savings, risk-taking, and working) and placing it on socially harmful activities (e.g., polluting) will reduce the economic burden of environmental protection, and should increase the overall level of pollution control without reducing economic growth in the process. For example, shifting a dollar from the income tax to an environmental tax will induce more labor force participation and increase the savings rate while reducing pollution damage (Heaton, Repetto and Sobin, 1990). This results in a policy that provides positive economic and environmental benefits for society.

The first priority in industrializing countries is to eliminate policies that have significant environmental costs or which create perverse incentives that encourage the depletion of resources and environmental degradation beyond the free market level. Economic instruments as they have been applied have not significantly encouraged industry to undertake environmental protection. Subsides (perverse incentives) such as depletion allowances, agricultural production and "cheap" water subsidies have resulted in environmentally damaging practices that counteract the positive effect of economic incentives. In many countries perverse incentives are coupled with economic incentives. Some countries allow for tax relief (e.g., rapid depreciation schedules) for cleaner production technologies, yet will also have substantial subsidies for environmentally damaging activities. Although there are many economic tools available for the promotion of pollution prevention, no single economic instrument can act uniformly to achieve the desired results unless perverse incentives which encourage overuse of natural resources are also removed (OECDb, 1992).

The reduction and elimination of policies that distort well-functioning markets or exacerbate market failures are top priorities in designing an effective economic incentive policy. An incentive mechanism is unlikely to be effective if there are countervailing forces present in the market promulgated by other governmental policies. The correction of market failures e., insecure property rights, unpriced resources and externalities) can be achieved through terventions that improve the free market result Examples of corrective economic policy clude road pricing in Singapore and the introduction of water pricing in China.

here are a wide range of options available to regulators who seek to improve both nvironmental quality and economic growth. By integrating the ideas of sustainability and sing the various market based incentives to encourage cleaner production practices, egulators can improve the environment and the economy in an integrated approach that hould reduce the cross-media transference of costs and benefits.

he goals of sustainable development can be achieved through the appropriate use of conomic incentives to encourage cleaner production practices. The diminishing stock of atural resources is forcing countries and individuals to view the environment in a new erspective. It is no longer a vast, undiminishable resource in which to dump unwanted by-roducts. Immediate measures must be taken to ensure future generations the ability to attain, t the minimum, the same economic and environmental conditions as the present generation. A new economic view of the environment, that fully incorporates its value, must be created n order to protect the valuable resource base--for this generation and the next. It is clear that the command-and-control approach has reached its upper bounds in its ability to effectively deal with environmental concerns. New and innovative approaches that incorporate new ideas into what types of products are produced, and how they are produced, are essential if the goal of sustainable development is to be achieved.

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Article David Pearce and Karl-Göran Mäler

Environmental Economics and the Developing World

NTRODUCTION

his special issue of Ambio focuses on the ontribution that environmental economics can make to a better understanding of esource degradation in the developing World Economics has a major role to play n

- explaining resource use and in particular resource degradation.
- measuring its impact
- designing policies to combat degradation.

The science of environmental economics is not new (1). Its theoretical underpinnings ie mainly in 'welfare economics'—the rescriptive analysis of how economies hould be organised so as to optimize human wellbeing Neoclassical capital theoy, and in particular that part of the theory hat deals with growth has also been relevant to the development of resource economics. But as a coherent body of thought, nvironmental economics did not develop roperly until the 1960s (2). Its application o *developing country* problems is more ecent still, and it is only in the last decade r so that significant advances have been made. The influence of environmental economics is, however, already apparent in evised policy analysis undertaken by international aid agencies such as the World Bank and the Asian Development Bank. The reorientation of policy requires that ending pay more attention to the environmental costs of development projects, and hat investments in the environment, soil onservation, afforestation, watershed protection etc., be given higher priority. Perhaps most significantly—general macroeconomic policy adjustment as is often required in structural adjustment loans—is ecognised to have environmental impacts which need to be accounted for. It is no onger enough to lend for projects and to nsist on currency devaluation as a condiion of the loan. It is necessary to ask what he environmental impacts of currency devaluation are. If they are negative, they ould threaten the sustainability of development. If positive, then they tend to reinorce the adjustment policy.

The analytical issues faced in developing country environmental economics are, y and large, no different to those faced in developed country. We need to know just ow *important* environmental degradation s and, thereby, how important environmental improvement is. This is the *measurement and valuation* task. We need to understand *why* resource degradation takes place and, in particular, how economic mismanagement through wrong pricing, ill-defined property rights and incentive structures contributes to environmental loss. This is the *explanatory* role for environmental economics. Finally, there is a need to devise the *best practicable* solutions aimed at 'sustainable development'. This is the *policy design* role of environmental economics.

SUSTAINABLE DEVELOPMENT

The broad policy objective of *sustainable development* was brought to the fore with the publication of the *Brundtland Report* in 1987 (3). Various interpretations of 'sustainability' exist, but an intuitive idea of an economic definition can be obtained as follows. If 'development' is defined as increasing wellbeing or welfare, then sustainable development is simply nondeclining welfare over time. It seems best to make this more precise and regard it as *per capita* welfare that needs to be continuously rising (or constant) (4). A path of development that makes, say, this and the next two generations better off but imposes costs on the third generation to come such that their welfare falls below current levels, is a nonsustainable path. The fact that we even discuss sustainability in this sense does imply something about our attitude to future generations. It implies that we have some concept of fairness to the future. Ethically, we do not permit a later generation to suffer because of damage done now. While difficult to formulate, this principle of *intergenerational equity* underlies the philosophy of sustainable development. If it didn't, we would have limited interest in the welfare of future generations. This ethical approach has some far-reaching implications for the choice of interest rate, the valuation of resources, the attitude toward risk, etc. These implications are discussed in more theoretical articles than the ones selected for this issue of Ambio.

Of course, welfare and development need not be synonymous, although the features of development, material wellbeing, education, basic freedoms, health, are all determinants of welfare. Over what time period is development to be sustained? That is a moot point, but the stress on sustainability has tended to refocus real-world policy debates on social, environmental and economic change over periods of at least several decades and perhaps a hundred years. That may seem modest by comparison with the concern of many environmentalists for future thinking lasting well into the distant future. But it is nonetheless a quantum leap from policy with a time-horizon set only by the date of the next general election. As an example, it is difficult to explain the current concern with global warming unless that shift in time horizon had taken place. Societies have always had concern for the future, but perhaps not as much as they do now.

Defining sustainable development is perhaps less interesting than elaborating the conditions necessary to achieve it. Here there is less consensus among environmental economists. One school of thought suggests that the future cannot be as well off as the past unless it inherits the same (or a larger) stock of capital as the passing generation possessed (5). The intuition here is that, with the same stock, there must be the same *capacity* to generate welfare. If the rule is kept and the generation fails to achieve rising or constant welfare, it seems reasonable to suppose that it is their mismanagement. This *constant endowment* approach might be best understood by analogy with business. No businessman survives or prospers by running down capital. His sustainable income is what he can take from the company without running assets down. Societies are no different. Capital depreciation now impairs the next generation's capacity to achieve the same level of welfare as this generation has.

But what is capital? Economists are used to defining capital widely to include not just the man-made assets (which we can symbolize by Km), but also the stock of human knowledge and skills (human capital, Kh) and the stock of nature's assets (natural capital, Kn). It is important to understand that natural capital is itself broader than stocks of oil and coal. It includes biomass in general, the ozone layer and biogeochemical cycles. All are *assets* since all generate a flow of services which humans consume (whether knowingly or not). Leaving capital intact, therefore, means leaving the aggregate of the three forms of capital intact (6).

The Standard National Accounts (SNA)

were developed during and immediately after the second world war with the objective of giving economists an empirical data base to analyze macroeconomic policies. Unfortunately, the central concept, the Gross National Product (GNP) was interpreted by politicians, journalists and others (but to a very small degree by economists) as a measure of national wellbeing, although it was defined for completely different purposes. GNP measures, in a broad sense the volume of production as indicated by market transactions. However, many and important parts of the total production process do not show up in market transactions and in particular, environmental resources are very seldom transacted in markets. Thus, their values are not recorded in SNA and consequently do not contribute to GNP. In view of the widespread use of GNP as a measure of wellbeing and the very serious defects connected with such use, several efforts have been made during the last five or so years to improve the national accounts. These efforts have partly focused on defining and estimating a better measure of aggregate wellbeing and partly to provide a better database for management of environmental resources.

It has been theoretically shown (7), that if environmental damages are accounted for in the national accounts and if the net changes in natural capital are appropriately included in the accounts, the Net National Product (NNP) will measure sustainability in the sense that it gives the maximum constant consumption path that would not impair the possibilities for wellbeing for future generations. In a sense, NNP so measured would be the return on the total capital; man made, human and natural capital. However, the empirical estimation of this NNP seems for the moment to be infeasible. On the other hand substantial improvements in the present SNA can be made by including the environmental damages that can be estimated in monetized form and by including the net changes in the stocks of natural capital. Repetto and his associates at the World Resources Institute have convincingly shown that even partial reforms of the accounting system may change our ideas whether an economy has been growing considerably or not. They tried to include into the accounts for Indonesia the depreciation of three stocks of natural capital — oil, timber and topsoil — and found that the official annual growth rate of about 7% between 1971 and 1984 should be reduced to 4%.

SNA consists of a large number of commodity and service accounts, which can be used for various economic analyses. One natural approach would be to extend these accounts to include stocks and flows of environmental resources. In that way we will get not only better information on the state of the environment and also information organized in such a way that we can apply standard economic models for an analysis of the interactions between the environment and the economy. This has been tried in many countries, notably in Norway and in France.

The system of national accounts can be seen as a statistical system monitoring the conventional economic areas. The work under way in many international organization—United Nations (8), UNEP and the World Bank (9), and in many countries will probably, in a couple of years, extend this monitoring system to include environmental resources, both in order to provide a better statistical database for economic analysis but also to yield an improved wellbeing performance index for nations.

ENVIRONMENT, VALUES AND SUSTAINABILITY

From an environmental standpoint, the generalized sustainability rule is problematic. If *aggregate* capital needs to be held constant, the rule is perfectly consistent with any constituent element of capital (Km, Kn or Kh) being run down, *as long as another constituent part of the overall capital stock is increased to compensate*. The Amazon forest can be destroyed as long as the proceeds are reinvested to build up say the stocks of roads, machinery or knowledge. As expressed so far, the sustainability rule offers no special role for environmental assets. They would be run down, or built up, according to their value relative to the value of other forms of capital. Indeed, this is how many economists would view the sustainability requirement. But even without an explicit role for environmental capital, this generalized sustainability rule is important.

(a) It explicitly acknowledges the relevance of environmental assets to any sustainable development plan. They count, whereas economic planning in the absence of this acknowledgement would mean that environment mattered not at all.

(b) The rule is clear in stating that losses of Kn must be compensated for by increases in Km or Kh (or both). *Sustainability is breached if the proceeds of environmental destruction are consumed.* Yet this is exactly what happens in many cases of natural resource use and extraction. Many commentators feel, for example, that the proceeds of North Sea oil (the rents) should have been reinvested by the United Kingdom to build up a new capital base, perhaps one based on biotechnology or computers or whatever. To some extent that has happened, but it also seems to be the case that UK residents have consumed much of the rent. Likewise, it is not at all obvious that Brazil or Indonesia have used the fruits of forest clearance to invest in new industries and a new capital base. In their essay, Edward Barbier, Jo Burgess and Anil Markandya clearly indicate this view of Amazonian deforestation, noting the role of subsidies in destroying the forest for the sake of negative product industries such as cattle ranching.

c) If there is to be a trade-off between Kn and other forms of capital, it is important to know what it is that is being traded off. We cannot know that in the absence of *values*. The benefits of increases in Km are measured by changes in GNP. But we should note the need to deduct from those
benefits the value of environmental
age done by the build up of Km. T
losses generally do not show up i
same way. They are not monetized
cause they do not appear in markets.
are *non-marketed costs.* If we build
dropower dam in a tropical forest, the
efits show up as electricity output, ir
tion water and flood control. All have
kets since the electricity and irrigatio
ter are sold, and flood control benefits
to be reflected in the value of agricu
production. But the resulting deforesta
or impaired water quality is not val
This explains why economists are
cerned to estimate the *economic* valu
natural capital services.

The valuation issue runs through a
ber of the contributions. Kerry T
shows the relevance of valuation me
ologies to decisions about wetlands,
of the functions of which are non-mar
ed. Alan Randall explores the philoso
cal basis of valuation in his essay. Pos
economic values arise when people's
ferences are met (benefits) and nega
values arise when people moved to
preferred states (costs). This generate
benefit-cost approach. Randall notes
many conservationists find monetary m
surement of environmental benefits
costs unacceptable. But many of the ob
tions to valuation fail because they req
a meta-ethical principle which itself
little appeal. Thus, it is thought to be in
ently wrong to reduce biological diver
If it is inherently wrong it must be w
regardless of the cost of maintaining d
sity. But the economic argument is
costs are foregone benefits. If maintain
diversity involves a cost of, say, X bil
dollars, the X billion dollars must
thought of as the benefits that would h
accrued had the money been used for
purpose. Since the money could have b
used for cancer research, hospitals, sch
or defence and armaments, it follows
the moral absolutism of the inheren
wrong school of thought places dive
conservation as a moral rule above any
saying that lower health standards
morally unacceptable. Simply put, t
are competing moral claims and there
there is a need for a higher order
principle to justify the preservationist
mand. As Randall notes, it is not
what that principle is.

Randall's own preference is more
attenuated form of benefit-cost anal
We might invoke the presumption
conservation is right unless the cost of
servation is unacceptably high in the
of the forgone benefits of developm
Such a presumption might be general
a case that he discusses), in which ca
would present us with an interesting re
sal of the development presumptio
land-use planning in the Western w
Development is typically assumed to
tacitly allowable, and it is for the cons
tionist to demonstrate otherwise. The al
native being contemplated is that dev
opment and conservation have equal rig
and neither is tacitly preferred. Rather th
make the rule general, it might be spec

particular locations of natural capital or remaining species. Much land-use planning does operate this way. Areas are protected and are subject to rigorous land-use controls. This latter approach is how Randall interprets *safe minimum standards* (SMS), i.e. conserving minimum stocks of natural capital in order that they can be regenerated if new information reveals a higher value for them.

Randall finds the maximize net benefits subject to a SMS constraint appealing. It avoids the absolutism of the *deep ecology* approach but softens the *moral hardness* of benefit-cost analysis (10). It forces a scrutiny, as does pure benefit-cost analysis, of the true benefits of development. If, for some reason, it is not possible to estimate the value of conservation, then we should scrutinise carefully the alleged benefits. This is the approach favored by Kerry Turner in his essay on wetlands. Moreover, it will often be the case that conservation values are sacrificed not just for low development benefits, but for negative benefits; i.e. costs. *Ex post* audits of many development projects reveal exactly this

In their article, John Dixon and Paul Sherman pursue the valuation issue in the very context of the kind of areas that tend to be the subject of *safe minimum standard* rules: national parks. In their review of the benefits of Khao Yai National Park in Thailand, they show that not only are there *use values* for the park, but there are *existence values* as well. The latter kind of value arises when there is a preference for conservation of an asset totally unrelated to actual or planned use. In the Khao Yai case, this is wild elephants. Although the authors do not pursue aggregation, the existence values appear to dominate the values they have so far obtained.

One approach to measuring the benefits from environmental improvements that has been extensively used in developed countries is the travel cost method The idea is to look at the amounts that people are paying for using an environmental resource and from that deduce what they actually would be willing to pay for the preservation of the resource. This approach is applied by Tobias and Mendelsson in the valuation of the tropical rain forests in Costa Rica.

INCENTIVE SYSTEMS

The second major strand of environmental economics, after valuation, is the role that economic incentive systems play both in explaining resource degradation and in solving it. In terms of explaining environmental loss, the emphasis is on the role of *below-market pricing*. This means that even where markets do exist, actual prices are below those that would clear the market. Typically, governments intervene to hold prices down, ostensibly to encourage development by lowering costs or to protect specific income groups. But such pricing encourages overuse of the subsidized inputs and these can give rise to environmental damage which then threatens the sustainability of the economic activity. Input subsidies for fertilizers, pesticides, agricultural credit, energy, irrigation water and land acquisition play a critical role in encouraging unsustainable agriculture and industry. The same factors have been at work in Eastern Europe, with devastating effect.

This underpricing theme is developed in several of the papers in this volume. Barbier, Burgess and Markandya show its relevance to Amazonian deforestation where, until recently, substantial subsidies were given for forest clearance. The tenure issue is important too. Land tenure is another economic incentive If tenure is secured then a farmer may be more motivated to invest in soil conservation by terracing or planting trees Tenure can work to the detriment of the environment too, for example, by being secured only if forest clearance occurs. Jan Bojö shows how subsidies to livestock and distorted price incentives contribute to land degradation worldwide, although he is careful to distance himself from popular estimates of soil loss based on deficient estimates, repeated uncritically in other literature Jeff McNeely and Robert Dobias show how tax systems contribute to overfishing in Thailand, and how modified incentive systems would contribute to reduced deforestation.

Many environmental resources have the nature of being common property resources and it has at least since Wicksell in the last years of the 19th century been known that such resources may not be efficiently utilized by decentralized decision making. The global or regional airsheds are examples of common property resources which have been used as recipients of airborne wastes and as no single country needs to take responsibility for the damage its emissions give rise to in other countries, the result is regional acidrain problems, depletion of the ozone layer, possible changes in the global climate (11). On the other hand, there are other kinds of common property resources, such as communal lands, and there has been an extensive discussion in the literature whether traditional societies manage such resources efficiently (12). Livingstone addresses this issue in his article on *Livestock Management and Overgrazing among Pastoralists* in which he looks both at individual and collective rationality for increasing the herd of animals. One important aspect is, he argues, that we have to include the insurance aspect of keeping a large herd. When a drought occurs, it will be beneficial to the owners to have a large herd Thus, we should look at the whole cycle between one drought and the next one in order to judge the rationality of a certain management scheme.

CONCLUSION

The message in these articles is consistent. If environment matters it will show up in the valuations carried out on essentially unpriced assets. Of course, valuation is not practicable on all occasions, but it is important to assess values whenever possible. The *causes* of resource degradation are complex. Popular sloganizing about the problem being one of poverty or population or multinationals or debt are unhelpful other than to point proper research towards testing the relationships between these issues and the environment. As yet we have comparatively few studies that test the relationships. Those that exist suggest that no single factor explains resource degradation and, often, environmental degradation is explained by a mix of factors, with the mix changing over time. But careful scrutiny of the economic signals at work shows that the way the economy is managed is very frequently the root cause of environmental degradation. If this is true, then there is a rich and policy-relevant field of research that needs to be explored by economists and others

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Valuing Environmental Resources

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Valuing Environmental Resources

Economics is about choice, where the possibility of making choices is limited by the available income. Each agent in the economy exercises his preferences over the choice set to maximize his satisfaction within his income. The sum of individual satisfaction is the total societal welfare. The price of a choice in the market thus reflects the valuation of the choice by society as a whole or welfare to the society from the choice. Under the condition of efficient markets the total valuation of all choices represents maximum welfare that a society can attain given its total income.

Most of the environmental resources do not have a market. Absence of markets does not imply that people do not have preference for such goods, e.g., improved air quality. Absence of markets does not imply that the environmental resources have no economic value. In absence of any mechanism to incorporate people's preference for these goods, the valuation of all choices does not represent the maximum welfare attainable by the society. Economics in environment is thus about capturing the preferences of people for environmental resources, such that the overall welfare increases.

The measure of comparison of diverse things in the economy is money. We have what economists term as inverse demand function that expresses the total benefits in monetary terms. Here the equivalence is that any benefit is equivalent to increase in welfare as it is equivalent to increase in income that can be used to increase welfare. Similarly any cost is decrease in welfare. Though there are things that cannot be given a money value, we should very clearly understand that the valuations here is of preference in face of resource constraints. Monetization of the benefits/costs of options related to environmental resources provide a measure of intensity of preference. This also helps in strengthening the case for or against a particular option. Option of environment resource availability is not a free option. It implies forgoing opportunity that could provide satisfaction to people. Monetization provides an opportunity to compare.

Total economic value of an environmental resource is sum of its *use value*, *option value* and *intrinsic value*. It is not necessary that each environmental resource have all the three values, especially so for the intrinsic value. Use value is value of resource that flows from consumption of service or goods provided by the environmental resources. Option value, as the word signifies, is an option to use the resource in the future. Intrinsic value is something independent of the humans. It is associated with non-human life form on earth, which is has a value irrespective of whether humans are there or not. It can be also interpreted as people's preferences of non-humans irrespective of there use to them, i.e., a non-use value. It is also termed by some authors as *existence value*. Two other non-use values reffered in the literature are *vicarious value* and *bequest value*. These two are again classified under option value of the resource.

Approaches to the economic valuation can be broadly classified as *direct* and *indirect* techniques. Direct methods are based on directly revealed preferences. Direct methods seeks directly to measure the money value of environmental gains. This is done either by either for looking for *surrogate markets* or by using *experimental techniques*. The surrogate market approach looks for a market in which goods or factors of production are brought and sold. The environmental benefits or costs are frequently attributes of those goods or factors. For e.g., risky environment is an attribute of certain jobs or air quality is feature of a house. The experimental methods simulates a market by placing the respondent in a situation in which he can express their hypothetical valuation of real improvement in specific environments. Indirect procedures use *dose-response* relationship between the change in state of environmental resource and associated effects. Example of this kind is effect of deterioration in air quality and the health damages; the effect of pollution on depreciation of material assets such as metals and buildings. Direct valuation methods are : *hedonic price method*; *travel cost method*; *contingent valuation method*

CVM - Valuing of Borivili National Park

Contingent valuation is a process of "asking" through a survey/questionnaire personal valuation of the respondent for increases or decreases in quantity of "the" environmental resource, contingent upon an *hypothetical* market. The advantage of this method is that it can be used to value a range of environmental goods and service and also can capture all the associated values. The disadvantage is that it generates preferences out of hypothetical situation. This methodology has been in use for almost 2 decades know and has seen a substantial refinement to increase the confidence in the methodology. This methodology has been used to value, improvement in water quality, valuation of endangered species, improvement in visibility, hunting access to game reserves, valuation of ecosystem, improvement in river water quality, etc.

Borivili national park is situated on the north-east of Greater Mumbai covering an area of 104 sq. km, one-fifth of Mumbai Municipality Region. It is home to many endangered flora and fauna species and also covers the watershed of lakes which supply 16 percent of mumbai's water requirement. It is unique in its being present in the heart of a cosmopolitan. The park maintenance is funded by the central government. It has been threatened by encroachment and habitat degradation from increasing population and commercial pressures of the urban settlement. The funding is not adequate to protect the park zone and also improve the quality of habitat. The study was an attempt to assess the preference of the mumbaikars to preserve the park and monetary value they put to it.

Respondents from different localities and income group for interviewed by trained interviewers through interview schedule. It was a two stage process. First survey was used to elicit major environmental problems that concern mumbaities. The questionnaire at this stage was also used to test the instrument for peoples comprehension. Subsequent to this the questionnaire was modified using the inputs from the response obtained. The respondents were given two scenario and asked what is there willingness to pay to move from scenario A to scenario B. To minimize the hypothetical bias and elicit a serious response people were told that they will have to pay in monthly installments for five years. The estimated mean willingness to pay is Rs 7.50 per household per month. This aggregated to a net present value of Rs 1033 billion. Respondents were also asked for the reasons for payment and the results reveal that existence and non-use values are a significant component of the total value put to the park by mumbaikars.

The Supreme Court of India has stayed the work on the main spillway on the Sardar Sarovar since a little over 2 years now. This, as also the long drawn struggle has raised strong, if somewhat shrill reactions from parts of Gujarat as also some other people in the country. The recurring theme of these reactions has been that the stoppage of work means stopping development - and the Narmada Bachao Andolan - the Petitioner in the case - has been accused of being anti-development and anti-Gujarat.

Even as the issue of rehabilitation is now acknowledged to be important, the a feeling remains that it should not come in the way of development - that projects cannot be stopped simply because of bad rehabilitation. In this context, it is important to understand the issues raised by the Narmada Bachao Andolan, for these are likely to have far reaching implications for the development projects all over the country.

It is not widely known that the one of the reasons for opposing the Sardar Sarovar project is precisely that it will not be "development". The project is sought to be justified, and indeed receives the wide spread support on the basis of the claim that it will be a permanent and total solution to the water problem of the drought prone areas Gujarat - namely Saurashtra and Kutch. However, a simply examination of the official map of the command area itself shows that only marginal areas of these regions are to receive the water - even on paper. Only 1.6 % of the cultivable area of Kutch and 9.24 % of Saurashtra will be getting the irrigation waters. Further, this too is uncertain as the hydrological estimates indicate that the water availability in the river had been overestimated at design by as much as 18 %. Which part of the command will bear the shortfall ? The water scarce areas, or the politically powerful areas of Kheda, Baroda and Ahemdabad that are in the early reaches of the command? The preparations for staking claims on the water is already seen from the fact that while the Project envisages that the waters will be spread over as large area as possible, and thus practically bans such water intensive crops as sugarcane, already licenses have been issue to 13 sugar factories in these earliest reaches of the command. Considering that sugarcane will take more than 8 times the water that is envisaged to be delivered per hectare, it is clear that the tail -enders will see a further drop in their share.

The project also claims to deliver drinking water to all the villages in Saurashtra and Kutch. However, the drinking water component is not even a formal part of the project - the project has no plans, nor the allocation of a single paise for this. It only promises to make available, at the canal head, 0.86 Million Acre Feet (MAF) of water for the domestic use. To make use of this will require the laying of an extensive network of pipelines, pumping and purification stations etc., something that is expected to cost around 5000 crore - outlays which are not in the project at all. And after all this, instead of being an quick and permanent solution to the water problem of the area, it will only substantially reduce the drought problem in Kutch and Saurashtra by say 2025 AD - according to the Central Water Resource ministry. Of course, this does not consider the fact that the project operation requires that the canal be closed down for two and half months of summer - thus, when the drought prone areas require the water most- they will be left to fend for themselves.

Clearly, the project will not solve, nor even dent the water problem of Saurashtra, Kutch - supposedly its justification.

Still the project will store a large amount of water. This water will certainly be used somewhere - will lead to development of some areas/ persons. Why should it not go ahead then ? No one, least of all the Andolan, is against development per se. However, the Andolan has raised some fundamental questions about the nature of this development, about its costs, and about its distribution. The first is, at what cost will these benefits be available - financial, social, and environment costs ? Today, it is clear that these benefits will require us to pay enormous costs in all these three areas. Secondly, who will then benefit from this? It is clear that the priority areas - Saurashtra and Kutch - are not going to get the benefits. The main beneficiaries will be the large farmers and big industries. Then, is such enormous state funding and high social and environmental costs justified ? For, should not the state s resources be conserved for those who are really the deprived and needy ? The last question is the most important - is there no other way of getting the same benefits without the attendant social and environmental costs ?

In fact, by raising the issue of the social and environmental impacts, and by showing that the project cannot go ahead without causing serious violations of the fundamental rights of the affected people, the Narmada Bachao Andolan has posed the last question as challenge to the society at large. It has questioned one of the most basic premises of the development process today - one can t make an omelet without breaking an egg . By asserting the fundamental right to life of the people, the Andolan has called upon the all sections of society - Government, scientists, intellectuals, scientists and engineers, social scientists, to come up with ways in which the benefits can be realized without the social and environmental costs. And it has done its own bit by identifying, documenting such means itself. The Andolan has pointed out how work done in the field - in the very drought prone areas of Gujarat - can address the water problem, without the human and environmental costs. And significantly, these means have proved to be financial cheaper, as also faster.

The Gujarat Land Development Corporation, a Government organization has shown how 15 MAF of utilizable water is available in Saurashtra itself, if one puts in place local rainwater harvesting techniques. Note that this is more that 1.66 times the total water that Gujarat will get from Narmada, several times more than the share of Saurashtra and Kutch, and 17 times more than the drinking water allocation. Also, this will be available locally, implying much lesser losses, and will be far cheaper than the SSP. The Swaydhyaya Parivar , a socio-religious movement whose head Shri Pandurang Shastri Athavale has received the Magsasay Award recently, has since last three years launched a massive well- recharging program in Saurashtra, benefiting over one lakh wells at minimum cost. This novel way of rain water harvesting has been a boon to the farmers suffering water scarcity. Many independent experts have shown, in great detail, how a combination of several such measure can very successfully address the water problem of this regions. Recently, the Gujarat Government itself announced a 500 crore project that will pump water from the Mahi and Narmada for drinking water purposes to Saurashtra - a way of using the Narmada waters without the question of displacement. Thus, the Andolan - when it challenges the project - is not opposing development, nor is it opposing the use of water for irrigation, nor does it say that power should not be used. But it has raised the issues of the how this should be done, for whom, and at what costs.

Of course, no such programs can work without due attention to the consumption side. If the water is required for industry, industry should move towards less water intensive processes, and as near 100 % water recycling as possible. If we want to grow sugarcane in Kutch, or continue the enormous, unregulated withdrawal of groundwater in the coastal zone of Gujarat, even five Sardar Sarovar projects may not be sufficient. It is imperative that the development of any region is in broad conformity with its basic ecology. Also, a certain amount of regulation will be unavoidable, and society will have to move towards minimum consumption - which of course does not imply less prosperity, but only means optimum utilization and curbing of waste. A draft groundwater regulation bill has been ready in Gujarat for many years, yet, it is not being taken up because of lack of political courage. It is far easier for the government to sell people the impossible dream of unlimited waters flowing in from the Narmada which will forever obviate the necessity of any control on consumption. This dream unfortunately can only lead to disaster, and of course abandonment of all prudence.

In the ultimate analysis, to pose the Narmada issue as a development versus no development debate is misleading, and a distortion of the real issues at hand. The real issue is simply how to move towards development that is socially just, environmentally sustainable, participatory, affordable and quick.

A Note on Number of PAP's in MP Entitled for Agricultural Land on Ressettlement

Prepared by
ARCH-VAHINI

A Note on Number of PAPs in MP who are Entitled for Agricultural Land on Resettlement

The displacement impact of the Sardar Sarovar Project in Madhya Pradesh (MP) has been deliberately exaggerated both by the Government of Madhya Pradesh (GOMP) and the Narmada Bachao Andolan As a result, they have been floating all sorts of figures regarding the number of PAPs who shall be completely uprooted and require land on resettlement at distant places Responsible ministers from the Centre have also now joined this game

The GOMP has claimed in its Action Plan of March 1993 that about 33,000 PAP families (including major sons) shall be displaced by the SSP in M P. and that about 14000 families of these shall have to be resettled in Gujarat It has mounted lot of pressure on the Gujarat Government to urgently acquire and make available about 28000 hectares of agricultural land for this purpose The Government of Gujarat too has accepted these figures and has not raised certain basic questions which need to be raised regarding these figures with the GOMP It is absolutely necessary that these questions are now raised as the GOMP has now openly started clamouring for the reduction of height of the SSP dam on 'humanitarian grounds'

We do not challenge the basic figure of 33000 PAP families in this note This figure is based on a detailed survey (86 column survey) in each of the affected villages. We were able to cross-check this data in few villages and have found that the basic data collected in this survey is of exceptionally high quality *We, however, argue on the basis of analysis of the same data that a large majority of these families are affected only in the sense that they shall have to be shifted at a higher plain in their own villages* This is due to the fact that most of the agricultural land in these villages will not be submerged This means that the number of PAP families who shall be completely uprooted and who shall have to be allotted agricultural land on resettlement at distant sites *would be much smaller than that reflected in the above figures.*

Let us now proceed to this task of analyzing the submergence data of M P As we have already noted, the GOMP has completed a detailed survey of all the 193 affected villages in M P It has also computerized the data collected in this survey. It has, however, not released crucial components of this information and has thus made the task of analysis difficult and complicated.

1. Extent of Submergence and Number of PAPs

Annexure I of M P. Action Plan of March 1993 gives village-wise extent of submergence of agricultural land and number of PAP families (both heads and major sons) for all the 193 affected villages *We have classified these villages in six different categories based on extent of land submergence in each village and then worked out the extent of submergence and number of PAPs for each village category.* We summarize this information in Table I below :

Table 1.

Extent of Submergence and Number of PAPs in each Village Category

Village Category based on % Agri Land Submergence 1	No of Villages 2	Total Agri Land Ha. 3	Submerging Land Ha. 4	% Submergence 5	Total PAP Heads 6	Total PAP Major Sons 7	Total PAP Families 8
less than 1%	54	15972	27	0.17%	4250	3793	8043
1- 10%	71	22313	1102	5.00%	5115	4065	9180
11-25%	25	8553	1258	14.80%	4042	3140	7182
26-50%	24	6662	2499	37.60%	2982	2722	5704
51-75%	12	1658	1042	62.90%	1095	855	1950
76-100%	7	696	643	92 40%	512	443	955
Total	**193**	**55854**	**6571**	**11.80%**	**17996**	**15018**	**33014**

Source: Annexture 1 of Action Plan of Resettlement and Rehabilitation of the Oustees of Madhya Pradesh, N.V.D A , March 1993.

Please note the following salient features of this table

- There is *virtually no land submergence (27 hectares out of 15972 hectares) in the first category (less than 1%) of 54 villages with 8043 PAP families.* It is clear that all the PAPs in these villages would only be required to be shifted at a higher plain in their own villages and no agricultural land shall have to be provided for their resettlement.

- *Similar situation would prevail for most of the 9180 PAP families in 71 villages of the next category (1-10%) where about 5% of the agricultural land (1102 out of 22313 hectares) will be submerged.* Thus there is very little agricultural land submergence in as many as 125 villages with 17223 PAP families.

- The extent of submergence increase as we go downward (≥11%). In order to arrive at a reasonable estimate of the number of PAP' families in the next four categories of villages who will require agricultural land on resettlement it is necessary to obtain information on the breakup of these PAP families in terms of those who loose agricultural land (25% or more of total land holding) and those who loose only houses.

2. Further Analysis of PAP Families in terms of Land and House Loss

Annexture I of the M P. Action Plan also gives breakup of PAP Heads for each village in terms of:

- those who lose only agricultural land,
- those who lose both land and houses and
- those who lose only houses

Such a breakup of major sons, however, is not given in this annexture. But, as we have already seen, figures of total major sons for each of the 193 villages are given.

From this we can approximately derive the breakup of major sons for each village by distributing major sons to each of the above subgroups in the same proportion as PAP heads are distributed, i.e., by dividing the figures of PAP heads for each sub group with total heads and then multiplying them with total major sons of the village This gives us the breakup of both heads and major sons for each village in terms of those who lose only land, those who lose land and house and those who lose only houses. From this we get the summary breakup for each village category just by adding the respective figures for the villages falling in each category as shown in Table 2 below:

Table 2

Distribution of PAP Heads and Major Sons according to the Pattern of their Loss.

Village Category based on % Agri Land Submergence 1	*No of Villages* 2	*Total PAP Heads* 3	*Heads losing only Land* 4	*Heads losing Both* 5	*Heads losing only Houses* 6	*Total PAP Major sons* 7	*Approx Major sons losing Land* 8 (a)	*Approx. Major sons losing Both* 9 (b)	*Approx. Major sons losing Houses* 10 (c)
less than 1%	54	4250	56	89	4105	3793	70	70	3653
1- 10%	71	5115	669	1164	3282	4065	595	893	2577
11-25%	25	4042	454	1100	2488	3140	297	835	2008
26-50%	24	2982	542	1492	948	2722	508	1371	843
51-75%	12	1095	90	638	367	855	70	504	281
76-100%	7	512	32	355	125	443	29	305	109
Total	193	17996	1843	4838	11315	15018	1569	3978	9471

Notes: a) derived by adding the figures of column 4/column3*column7 for each village.
b) derived by adding the figures of column 5/column3*column7 for each village.
c) derived by adding the figures of column 6/column3*column7 for each village.

From this we derive following Table 3.

Table 3.

Distribution of PAP Families (Heads + Major sons) in each Village Category

Village Category based on % Agri. Land Submergence 1	No. of Villages 2	PAP Families losing Land or Both 3 (a)	PAP Families losing only Houses 4 (b)	Total PAP Families 5
less than 1%	54	285	7758	8043
1- 10%	71	3321	5859	9180
11-25%	25	2686	4496	7182
26-50%	24	3913	1791	5704
51-75%	12	1302	648	1950
76-100%	7	721	234	955
Total	193	12228	20786	33014

Notes: a) Sums of Columns 4,5,8 and 9 of Table 2
b) Sums of Columns 6 and 10 of Table 2

- Thus as many as 20786 families out of 33014 would lose only their houses while 12228 families would lose either their land alone or both land and houses.

- On the first sight it would appear that at least all the 12228 families who lose their land, shall have to be given alternate agricultural land at the resettlement sites.

    - This, however, is not correct as this *figure of 12228 families also includes those families who lose less than 25% of their total land holding.*

    - Tribunal had provided that such families have to be given only cash compensation for the land they loose

    - Alternate land has to be given only to those families who would lose 25% or more of their total land holding

    - It is most amazing that the GOMP has not taken into account this important policy provision and not given separate figures of those PAPs who would lose more than 25% of their land holding

- Without this further breakdown of the PAP familes who lose land it is not possible to arrive at an accurate estimate of the number of families who shall have to be allotted agricultural land.

- But a reasonable estimate can be made from the distribution of these families in different village categories

- The fact that 6292 such families are located in the first three categories (land submergence less than 25%) suggests that a large proportion of these families would loose less than 25% of their land holding.

- We would take this factor into account while calculating the number of families who are entitled to alternate agricultural land on resettlement.

- On the other hand *some of the 20786 families (Column 4) who loose only houses will be entitled for alternate agricultural land.* This category of families is actually composed of three different types of families:

  a. Landed families who only lose their houses,

  b. Landless agricultural labourers who do not own any land but work on the agricultural land in the submerging villages and

  c. Other Landless families who are engaged in non agricultural activities like trade, fisheries etc.

- Of these types at least some of the Landless agricultural labourers, especially those who reside in villages where most of the agricutural land will be submerged, shall be entitled for agricultural land at the resettlement sites.

- Here again the GOMP has not released the necessary breakup of these families although it has the necessary figures. It is claimed in the Action Plan that the relevant village wise category-wise figures of landed, landless labourers and other landless families have been separately published as 'Statistical 'information' However this publication has not been made available to us despite repeated requests As far as we are aware the officials of the Sardar Sarovar Punarvasvat Agency have also not received this publication.

3. **Distribution of Landed, Agricultural Landless and Non-agricultural Landless Families:**

- Although village-wise figures of landed, landless agricultural labourers and other landless families are not given in the Action Plan, a summary table is given on page 14 of the Action Plan. According to this table out of total 33014 PAP families:

  a. 19725 families are landed and their major sons,

  b. 9188 are landless agricultural labourers and their major sons

  c. 4101 are other landless and their major sons.

- From Table 3 above we know the distribution of 12228 families losing land (Column 3) and 20786 families losing only houses (Column 4) in each village category

- From this we derive the approximate distribution of the landed, landless labourers and other landless families in each village category as under:

  a. Multiplying the figures of Column4 of Table 3 with the figure of total landless agricultural laboures (9188) and dividing it by total families losing only houses (20786) gives the distribution of landless agricultural labourers in each village category

  b. By replacing 9188 with 4101 (total other landless families) in the above calculation we get the distribution of other landless families in each village category.

  c. Substracting the above two sets of figures from the figures in column 4 gives the distribution of landed families loosing only houses Adding the figures of column 3 to these figures would give us the distribution of all the landed families in each village category The sum of these figures comes to 19725 which is same as the total landed families.

- We give the result of these calculations in Table 4 below

Table 4.

Approximate Distribution of Landed, Agricultural Landless and Non-agricultural Landless families in each Village Category

Village Category based on % Agn Land Submergence 1	*No. of Villages* 2	*Landless Labourer Families* 3 (a)	*Other Landless Families* 4 (b)	*Landed Families* 5 (c)	*Total PAP Families* 6
less than 1%	54	3429	1530	3084	8043
1- 10%	71	2588	1154	5438	9180
11-25%	25	1988	888	4306	7182
26-50%	24	792	354	4558	5704
51-75%	12	287	128	1535	1950
76-100%	7	104	47	804	955
Total	193	9188	4101	19725	33014

Notes: a) (Column 4 of Table 3) * 9188 / 20786

b) (Column 4 of Table 3) * 4101 / 20786.

c) (Column 4 of Table3) -(Column 3 of Table4)-(Column 4 of Table4)+(Column 3 of Table3)

4. Estimate of PAP Families who are entitled to Agricultural Land

With this information we now proceed to the main task of this note, i e., to arrive at the reasonable estimate of PAP families in M P who are entitled for agricultural land on resettlement

- As we have already noted above only 27 hectares out of 15972 hectares would be submerged in the first category of 54 villages (land submergence less than 1%). Hence we can reasonably expect that almost all the 285 families losing land (Column 3 of Table 3.) in this category would lose less than 25% of their land holding Similarly none of the 3429 Landless labourer families (Column 3 of Table 4) in these villages would be entitled to land as hardly any land would be submerged Thus not a single family in these villages would be entitled for agricultural land in this category.

- For next 71 villages (land submergence 1-10%) we have assumed that although it is unlikely at the most about 822 of the 3321 (25%) families losing land could lose more than 25% of their holdings and thus require land However since only 5% of the total agricultural land in these villages is undergoing submergence, hardly any landless labourer could be affected

- In next 25 villages (land submergence 11-25%) we assume that 35% of the landed families losing land and 25% of the Landless agricultural labourers would be entitled for land while in next 24 villages (land submergence 26-50%) we assume this figure to be 50% for both the categories.

- In remaining 19 villages (land submergence more than 50%) we assume that all the landed families losing land and all the Landless labourers would be entitled for land

- Thus as shown in Table 5 below at the most about *7036 families out of 33014 families* would require agricultural land on resettlement while the remaining 25641 families need to be shifted at a higher plain in their own villages with no requirement for agricultural land

Table 5

Estimate of PAP Families entitled to Agricultural Land

Village Category based on % Agn Land Submergence 1	No of Villages 2	Approx Families Entitled to receive Agn Land			Approx. Families not Entitled to receive Agri. Land		
		Landed 3	LLabourer 4	Total 5	Landed 6	Other 7	Total 8
less than 1%	54	0	0	0	3084	4959	8043
1- 10%	71	831	0	831	4607	3742	8349
11-25%	25	941	497	1438	3365	2379	5744
26 50%	24	1957	396	2353	2601	750	3351
51 75%	12	1302	287	1589	233	128	361
76 100%	7	721	104	825	83	47	130
Total	193	5752	1284	7036	13973	12005	25978

No doubt these are statistically derived numbers only, but they give fairly accurate picture, if anything assumptions made are more in favour of land entitlement giving almost certainly higher side of estimate, of the scale and nature of the resettlement problem in MP. We must now take up this issue with the Government of MP and ask it to furnish all data it has collected so that more accurate picture of the problem can be obtained. We should also emphasize that this is the estimate of total PAP families in M.P. who shall be entitled for land and not all of them can be expected to resettle in Gujarat.

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March 24, 1994.

Water Resources

By

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WATER RESOURCES SCENARIO IN INDIA

Till a few years back, there was a general feeling that our country has abundant water resources. In the last decade, it has been realised that the precious natural resource of water is already scarce and the situation is going to be increasingly acute in the future.

The country gets an annual average precipitation of 400 m. ha.m. The total quantum of water flowing through various rivers is only 187 m. ha.m. (47% of rainfall). However, utilisable quantum of surface water is only 69 m. ha.m., i.e. 37% of available water. This is mainly on account of the fact that the rainfall occurs only for 3-4 months in a few spells. We do not have adequate storage sites to store most of this water for subsequent utilisation throughout the year. In addition, we have utilisable ground water of about 45 m. ha.m. Thus the total utilisable quantum of water is only 114 m. ha.m., i.e. 28% of total rainfall, balance going waste.

In 1951, actual utilisation of surface water was 20% and of ground water 10% of ultimate utilisable quantum. In 1990, these percentages rose to 55% and 50% respectively. During this period, irrigated area rose from 22 m. ha.m. to 82 m.ha. (1993) and food grain production from 53 M.tonnes to 170 M.tonnes, touching a peak of 195 M.tonnes last year, which is just adequate for the present population.

The projected population in the year 2000, is 1000 million, requiring food production of 270 M.tonnes. In the year 2025, food production will have to be 365 M.tonnes to feed a population of about 1350 million. Bulk of the increase has to come from irrigated areas. Even after full development of our irrigation potential of 115-120 M.ha; only 65% of the net sown area will be irrigated and the balance 35% will still be subject to vagaries of monsoon

At the same time, there is a continuous increasing demand for domestic and industrial water supply. In 1987, the author prepared the water demand scenario for the years 2000 and 2025. This brought out that total water use will increase from 56 m. ha.m. in 1990 to 79 m. ha.m. in 2000 and to 112 m. ha.m. in 2025.

Thus, the entire quantum of utilisable waters would be fully consumed by 2025, while the demands will still continue to grow.

In view of this grim scenario, it is imperative to conserve as much water as possible and optimally utilise the same. Conservation has three broad connotations; (i) Maximum possible storage of rain water through large, medium & small dams, (ii) Economical & Optimal use including prevention of wastages & leakages; and (iii) Multiple use involving Recycling and Re-use wherever possible.

Storage of waters is necessary not only for irrigation, but also for hydro power generation, drinking water supply to urban areas, industries, etc. Our ultimate storage capacity through large, medium and small dams together is about 30 m. ha.m. (i.e. only 16%) of average annual surface flows. The capacity created so far is about 20 m. ha.m. through 3600 major dams and about 2 lakh minor dams, the latter contributing only about 3 m. ha.m. i.e. only 10% of the ultimate storage capacity. U.S.A., with the same quantum of average annual surface water availability has already built about 8300 storage dams with a storage capacity of 70 m. ha.m. (i.e. 230 of India's ultimate storage, while Erstwhile U.S.S.R. has about 12,000 dams with a storage capacity of 110 m. ha.m.

However, with the present misconceived opposition to construction of storage dams, it is doubtful whether even the limited storage capacity can be created. In what eventuality, the projections of utilisable quantum of water will go awry, and much before 2025, the country will face a serious situation. Already; major cities like Madras, Hyderabad, Bangalore and many other smaller towns are facing acute shortage of water. With inevitable rapid pace of urbanisation, the problems of urban water supply are bound to be acute

At present, water use in all sectors is wasteful and sub-optimal needing a concerted and vigorous drive for optimal and economic utilisation. At the same time, it needs to be appreciated and understood that the controversy being created by some persons between large and small dams and between use of surface water and ground water is totally misconceived All of these are complementary and supplementary to each other and not substitutes. It is no exaggeration to say that the Nation's survival and future economic growth will to a large extent depend on optimal Water Resources Development & Management.

Air Pollution

By

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EAST-WEST CENTER

The U.S. Congress established the East-West Center in 1960 to foster mutual understanding and cooperation among the governments and peoples of the Asia-Pacific region, including the United States. Principal funding for the Center comes from the U.S. government, with additional support provided by private agencies, individuals, and corporations, and more than 20 Asian and Pacific governments.

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FUEL COMBUSTION, AIR POLLUTION EXPOSURE, AND HEALTH: The Situation in Developing Countries

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KEY WORDS urban air pollution, indoor air pollution, total exposure assessment, health effects, particulates

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SUMMARY

As described in the Appendix, there are a number of recent studies of air pollution in developing-country cities (2-5, 17, 99, 100), each of necessity relying heavily on the one available source of comparative international

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ambient monitoring data, Global Environment Monitoring System (GEMS) (6a,b–10).[1] In this review, therefore, rather than simply reproduce the GEMS data, I have chosen to examine developing-country air pollution from the standpoint of a useful analysis technique that has been under development in recent years "Total Exposure Assessment." Basically the review is composed of four parts

1. A brief description of the historical and current relationship between energy use and air pollution
2. An explanation of the idea of exposure assessment and the power that it can bring to analyses of the health impacts of air pollution.
3. Focusing on developing countries, a global exposure assessment, combining demographic data with GEMS outdoor data and less-developed country (LDC) indoor air-monitoring studies
4. A review of the health effects literature relevant to the micro-environments found to harbor the largest human exposures.

INTRODUCTION

Today, as throughout human history, most direct human energy needs are derived from combustion, and the bulk of the fuels burned (by mass) are solids, principally wood and coal. Unlike gases and liquids, solid fuels require relatively advanced technology to be pre-mixed with air or otherwise ensure their complete combustion. The airborne emissions of incomplete combustion products, such as carbon monoxide, particulates, and volatile organic compounds, have been extensive. Small-scale combustion of solids (less than a few kilograms per hour) has so far been particularly difficult to keep clean with simple inexpensive devices. Also, in its natural state, coal, to a much greater extent than oil and gas, but unlike wood, typically contains sulfur, ash, trace metals, and other contaminants that add significantly to the emissions burden. In addition, all carbonaceous fuels are responsible for releases of other airborne pollutants, nitrogen oxides and carbon dioxide prominent among them.

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[1] The basic source for internationally comparable urban air pollution data is the Global Environment Monitoring System (GEMS/Air) of the United Nations Environment Programme (UNEP) and the World Health Organization (WHO). Since starting in 1974, shortly after the Stockholm Environment Conference, GEMS has built up a system that now collects comparable ambient air pollution data in about 50 cities of 35 countries, spread by geography and income (6ab). Typically, SO_2 and total suspended particulates (TSP) have been monitored in three stations of each city, one each in industrial, commercial, and residential zones. More recently, GEMS also collects monitoring data for CO, NO_2, and Pb and makes emissions estimates for all five pollutants. The results are published periodically by GEMS and also often appear in other periodic international data sets, such as those by the World Bank (7), the World Resources Institute (8), the United Nations (9), and UNEP itself (10).

Human-engendered combustion, thus, has always had many direct and indirect impacts on atmospheric composition and processes. Thousands of generations ago, humanity's mastery of fire led to biomass combustion that not only contaminated local living environments with smoke but also, through sometimes vast changes in natural landscapes, had a significant role in the global cycling of atmospheric constituents, particularly carbon (11abc).

With the rise of cities, where fuel combustion and other polluting activities are geographically intensified, however, pollution at a scale of a few kilometers became conspicuous. Indeed, so conspicuous that air pollution science grew to maturity in the 20th century by focusing on community pollution to the near exclusion of attention to other scales. As explained below, however, the principal effect of interest, ill-health, is arguably addressed more efficiently at smaller scales. In the 1980s, local (scale of a few meters), regional (hundreds of kilometers), and global effects came to greater attention as evidenced by the fairly rapid rise of interest in indoor air pollution, acid precipitation, and greenhouse and ozone-damaging gases.

As happened over a somewhat longer period in the currently developed nations, urbanization and energy intensification have made urban air pollution a growing problem in many less-developed countries (LDCs).[2] Much has been learned in the intervening years, however, about how to think about and manage this problem.[3]

WHERE IS AIR POLLUTION?

There are a number of points at which air pollution might be measured and controlled. Which are the best choices depend on the ill-effects of concern, the understanding of relevant environmental pathways, and the resources available. For health effects, it is useful to consider the generic environmental pathway illustrated in Figure 1, which spans from type of fuel used at one end to actual ill-health at the other. Monitoring can be applied at any stage, as can intervention measures. At the extreme right is the matter of concern, human health, but for guiding control decisions, which have mainly addressed fuel type and emissions, it is too late in most circumstances to rely on measurements after ill-health occurs. In addition, in most cases, the health effects are nonspecific, i.e. have many risk factors. Fuel type, on the other hand, while easy to measure, is only a crude indicator of the outcome of interest, by virtue of the many steps between it and actual ill-health.[4]

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[2] Here defined to exclude the countries of Eastern Europe and the former Soviet Union, although many have severe air pollution problems as well (11d). Unfortunately, however, GEMS and other data are generally not available for these nations

[3] In the early 1990s, urban air pollution in developing countries came to be the focus of a number of international studies. As described in the Appendix, the results of these studies add significantly to the information about the levels, sources, and control options for LDC urban air pollution

When community concentrations rose during industrialization, it was natural to measure the pollution where it was most obvious and unavoidable, outdoors. Perhaps not always consciously addressed, but nevertheless inherent in this approach is the assumption that these measurements are an appropriate compromise among the exigencies of monitoring, the need for a responsive indicator of the outcome of control measures, and the desire for a reasonable indicator of health effect. Traditionally, ambient concentrations are measured on the tops of public buildings and other secure and convenient outdoor locations spread across cities.

In reality, as seen in Figure 1, health effects are not due directly to ambient concentrations, but rather to the doses of pollutant received. Doses, in turn, reflect not ambient concentrations, but the concentration in the air actually breathed by people, i.e. exposure. Thus, to understand the potential health impact of air pollution it is important to measure at the places where the people are (12).

The idea of measuring where the people are, i.e. focusing on exposures rather than ambient concentrations, is one of the principles of Total Exposure Assessment (TEA), a rapidly growing branch of environmental health sciences.[5] In its complete expression, TEA involves the measurement of pollution at all the boundaries of the body; the air, food, water, and substrates to which the body (respiratory system, gastro-intestinal tract, skin) is exposed (13ab). For some pollutants, e.g. carbon monoxide, only one route is important. For others, such as lead, measurements of several routes are

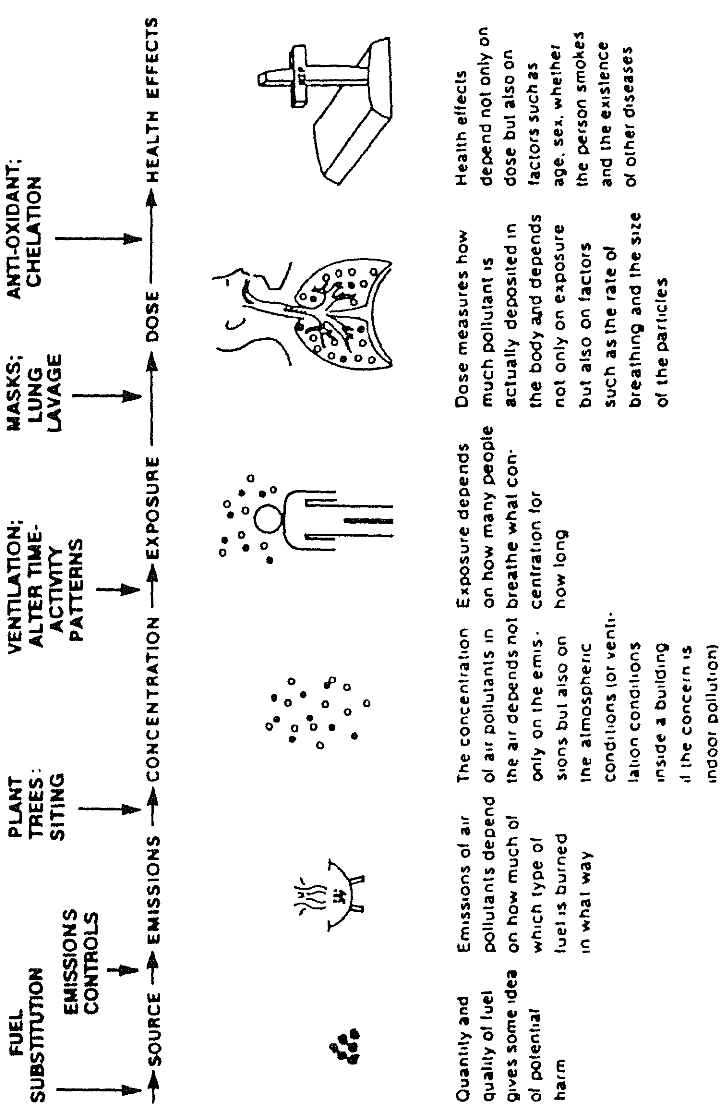
FUEL SUBSTITUTION
EMISSIONS CONTROLS
PLANT TREES: SITING
VENTILATION; ALTER TIME-ACTIVITY PATTERNS
MASKS; LUNG LAVAGE
ANTI-OXIDANT; CHELATION
SOURCE
EMISSIONS
CONCENTRATION
EXPOSURE
DOSE
HEALTH EFFECTS
Quantity and quality of fuel gives some idea of potential harm
Emissions of air pollutants depend on how much of which type of fuel is burned in what way
The concentration of air pollutants in the air depends not only on the emissions but also on the atmospheric conditions (or ventilation conditions inside a building if the concern is indoor pollution)
Exposure depends on how many people breathe what concentration for how long
Dose measures how much pollutant is actually deposited in the body and depends not only on exposure but also on factors such as the rate of breathing and the size of the particles
Health effects depend not only on dose but also on factors such as age, sex, whether the person smokes and the existence of other diseases

Figure 1 Environmental pathway for combustion-derived health-damaging air pollution. Measurement and control of health-damaging air pollution can be initiated at any of these stages. Note sample control options in the top row. There are, of course, more options further to the left, for example, changes in energy efficiency such that no fuel at all is needed for a particular task or, even, a decision not to perform the task at all. See (12ab).

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[4] Given data and space constraints, it is not possible to present an inquiry for the range of pollutants necessary to obtain a complete picture of LDC air pollution. Rather, I focus on health-damaging pollution in general and particulates in particular. This is justified here because:

(A) Although a number of other impacts are of growing interest, to date most regulation and control efforts around the world have been designed to avert ill health;

(B) If it is only possible to use one pollutant to indicate potential health effects, particulates are probably the best choice in most circumstances where combustion is the principal source,

(C) Partly due to B, but also because of the relative ease of measurement, there are more and better data around the world on concentrations of particulates than on any other air pollutant,

(D) Only one pollutant is needed to illustrate the total exposure approach used here. Even so, there are significant data gaps that force me in places to make estimates and to most rely on data from India and China, which, however, do contain half of LDC population and burn three-quarters of LDC solid fuels.

[5] Now, for example, with its own scientific society, International Society of Exposure Analysis, and publication, *Journal of Exposure Analysis and Environmental Epidemiology*

needed in order for health effects to be determined accurately and adequate control measures to be designed.

As with other important paradigmatic statements, the principle that pollution ought to be measured where the people are may seem obvious once stated (14). Yet, it has not been followed in the vast majority of research, monitoring, control, and regulatory efforts aimed at health-damaging air pollution (15–17).[6] Until relatively recently, most attention has been paid to the concentrations on tops of post offices and other outdoor locations where most people spend very little time (18, 19).[7]

There are many reasons to be concerned about air pollution, human health being only one. For some of the other ill-effects, e.g. loss of visibility, property, or crops, ambient measurements may be adequate, although even with these endpoints exposure measures may be better (20ab).[8] Most community air pollution research, measurement, regulation, and control programs, however, have been and continue to be concerned with human health.

Ambient measurements might be sufficient for handling health effects if they indicated population exposures and doses accurately. Unfortunately, however, in many cases they do not. Depending on the situation and pollutant, the pollution actually inhaled by people may be significantly higher or lower than indicated by, even nearby, ambient monitors (21, 22).[9]

Focus on exposure, a function of pollutant concentration and the time over which people experience it, instead of ambient concentration, has three important consequences (23ab):

1. It changes, sometimes dramatically, the health relevance of outdoor sources that significantly affect ambient concentrations;
2. It uncovers a whole new landscape of sources, usually local, that have significant impacts on exposures, even though having essentially no impact on ambient concentrations, and
3. It reveals a much larger set of management options than simple source-control.

Furthermore, some of the results of past studies linking health and ambient air pollution may have to be rethought as should any sanguine conclusions that reduction in ambient level, by itself, has led to significant decreases in exposure (24).

An Example of the Power of Exposure Assessment: Coal Versus Tobacco

Although coal-fired power plants in the United States are well controlled, they still emit about 0.4 Mt of particulates annually, or 1.6 kg per person. In contrast, only 50 g of particulates is released into the surrounding air for each person in the United States as Environmental Tobacco Smoke (ETS) by the average 2080 cigarettes smoked annually per capita (Table 1). For controlling ambient concentration, the ETS hardly counts, representing only some 3% of the particulate mass from power plants

In terms of exposure, however, the relationship is quite different. Because US power plant emissions are generally released high in the air away from populated areas, the amount that actually reaches people is quite small (25).[10] Much ETS, however, is indoors, trapped in the same volume of air breathed by many people for many hours. Based on US measurements, the ETS released in households is thousands of times more likely to reach people's lungs than particulates from power plants. If 90% of all cigarettes are smoked indoors, in households, workplaces, and elsewhere where the mean daily occupancy is 2.5 persons, the relative exposure is some 80 times higher for ETS, even though ETS emissions are about 30 times lower (Table 1).[11]

As for control options, a 1.3% reduction in ETS would be equivalent (for particulate exposure) to eliminating all the coal-fired power plants in the country. This could be done by reducing the number, size, or smokiness of cigarettes. The population exposure due to burning about one tonne of coal in a controlled US power plant could be countered by eliminating the

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[6] In 1984, after some background reports (e.g. 15), WHO and UNEP conducted the Human Exposure Assessment Location (HEAL) Project, which facilitates research and information sharing among 10–15 institutions worldwide concerned with exposure assessment for a limited number of pollutants (16). Unfortunately, although providing important functions, the HEAL Project has not had the mandate or anything approaching the resources required to actually make comparable international estimates of population exposures (17).

[7] Most popular textbooks (e.g. Ref. 18) and global reviews (e.g. Ref. 19) do not cover exposure assessment and indoor air pollution

[8] For example, much can be learned by linking individual pollution sources to the acid rain falling downwind on particularly vulnerable ecosystems, rather than to area-wide measurements (20ab)

[9] For example, a number of studies in the United States have shown that even backyard monitors do not well represent the daily exposures of people living in the adjacent houses. Monitors on the nearest public building are even less accurate (12, 21). Evidence of this phenomenon is also found in developing countries (22).

[10] Based on a study of several hundred power plants, Rowe (25) calculated that one tonne of annual particulate emissions would produce about 100 $\mu g/m^3$ of exposure to one person over the year

[11] These calculations ignore the considerably larger "active smoking" exposures to the smokers themselves.

Table 1 Coal versus tobacco smoke in the United States An exposure analysis for the year 1990[a]

	Unit	Coal-fired power-plant smoke	Environmental tobacco smoke
Total fuel	MT	700	5
Emissions per capita	kg	1.6	0.05
Total emissions	MT	0.4	0.01
Exposure effectiveness	kEU/t[b]	0.1[c]	240[d]
Nominal dose effectiveness	g/t	1	2,400
Population exposure	kEU	40,000	2,400,000
		Equivalences	
Fuel		1.0 tonne coal	1,000,000 cigarettes
Emissions		1.0 tonne coal (controlled)	24,000 cigarettes
Exposure		1.0 tonne coal	10 cigarettes

[a] Source: updated and expanded from (94) with data from (95)
[b] kEU = kilo exposure units, see footnote 15, text
[c] Based on a study of several hundred US power plants (25)
[d] Based on 1 ($\mu g/m^3$)-day per cigarette (96), an emission factor of 24 mg per cigarette (97), and 2.5 people exposed at a time

ETS from only 10 cigarettes.[12] Control can also be achieved, however, by enhancing building ventilation, no-smoking zones, smoking bans, and so on, control efforts that may not change emissions at all, but still greatly reduce exposures.[13]

These calculations indicate that, from the standpoint of cost-effectiveness of particulate exposure reduction, we ought to be willing to pay some 2400 times more per gram to reduce the particulates in ETS compared to those in coal-fired power plant emissions Given the large amounts of money spent to control emissions from power plants, if such a cost leverage were institutionalized through taxes, subsidies, or tradeable permits, there would presumably be much innovation in ETS control techniques.[14]

This approach does not justify ignoring outdoor concentration and outdoor sources, but rather provides a means to prioritize all sources according to their impact on human health. It also does not justify ignoring that outdoor sources affect indoor concentrations and vice versa Any source is judged by impact on total exposure, whether occurring indoors or out.

This coal/ETS example is chosen to illustrate the extreme difference that exposure assessment can make in air pollution analysis, but is not unrelated to the issue at hand. In many developing countries, unlike the United States, tobacco use is growing, in some places rapidly (26). Thus, even if local conditions are quite different from those in the United States, i e. power-plant particulates are not released out of town and high in the air, the rise in ETS exposures may start to add significantly to those from large outdoor sources.

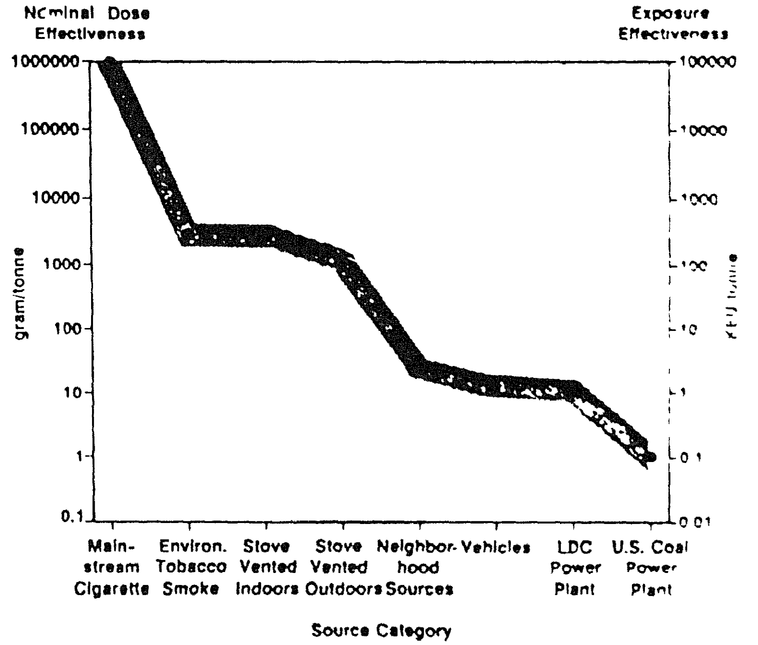

Figure 2 Preliminary exposure effectiveness (EE) and nominal dose effectiveness (NDE) estimates Here the EE and NDE are estimated for air pollution sources in LDC cities ranging in scale from personal (cigarettes) to regional (remote power plants) Mainstream tobacco smoke is assigned an NDE of 1.0 (1.0 tonne/1.0 tonne) since, by definition, it is all inhaled Sources are generic and estimates are uncertain, as indicated by the broad and continuous band connecting these sources Note the log scale

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[12] For the smokers themselves, 1 cigarette produces the particulate population dose equivalent to 30 tonnes of coal burned in US power plants.

[13] Recently, per capita US cigarette consumption has been declining at about 4% per year. This, combined with more ETS regulations, such as no-smoking areas in public buildings, is undoubtedly responsible for a total annual reduction in particulate exposure equal to several times the remaining exposure from coal-fired power plants.

[14] There are, of course, a number of other considerations besides particulate exposure in decisions to control either ETS or power-plant emissions, although perhaps no other single consideration is as important.

Exposure Effectiveness

Exposure effectiveness (EE) is the fraction of released material that actually enters someone's breathing zone as measured in exposure units.[15] Another measure, the "nominal dose effectiveness," is the ratio of emitted to inhaled material (leaving aside how much is actually deposited in the body). The extreme variation of EE for sources of different types is illustrated in Figure 2. Here, one extreme is taken to be mainstream tobacco smoke, which, by definition, is entirely inhaled by smokers. In the figure, therefore, mainstream tobacco smoke is shown at 100,000 kEU/t, which is roughly the exposure equivalent of its defined level of 1,000,000 g/t (100%) nominal dose effectiveness.[16]

Since Figure 2 has a log scale, there is no zero, but some sources have extremely low EE. For example, as shown in Table 1, the EE of the median coal-fired power plant in the United States is only about 0.1 kEU/t (1 g/t nominal dose), about 6 orders of magnitude less than mainstream cigarette smoke.

As illustrated in Figure 2, most other source types of interest fall between these two extremes. ETS released in a US home, for example, produces some 240 kEU/t (Table 1). Stove smoke indoors is shown to have a similar EE, although stove smoke released immediately outdoors is about one-third as effective at producing exposure. These EEs obviously depend on local situations, being much lower with isolated tightly sealed houses in windy environments, and higher in crowded wind-shielded slums in the tropics. The EE of vehicles depends on how and where they are used.

Figure 2 should be taken as only broadly illustrative of the kind of EE variation that exists. The wide band is shown to indicate that there can be great variation due to the characteristics of the particular micro-environments. For developing the most effective and timely controls that are directed toward exposure rather than just toward emissions or ambient concentrations, the EE of each major source category needs to be determined for each city. This is not as difficult as it might sound, for it is possible to group most sources into a limited number of categories and to determine EE for each group without doing either source inventories or diffusion/dispersion modeling (27).[17]

GLOBAL EXPOSURE ASSESSMENT

Accepting that exposure is a better indicator of health impact than emissions or ambient concentrations and that sources have widely disparate EE, the TEA principle specifies that pollution ought to be measured where the people are.

Where, Then, Are the People?

Figure 3 attempts a rough answer on a global basis by dividing up total human person-hours into eight categories based on three distinctions: developed versus developing countries; urban versus rural; and indoor versus outdoor. Table 2 shows the demographic data used to make the estimates.

Unfortunately, there seem to be few studies of time use in developing countries that would help determine how much time people spend indoors (28–30).[18] Studies in developed countries, however, show that more than 90% of person-hours is spent in indoor micro-environments (31). The fraction of the rural population involved in agriculture can be used as a rough indicator of the time spent outdoors in rural areas. Similarly, the fraction of the urban population living in slum housing, much of which is well ventilated and small, is an indicator of the time spent outdoors in urban areas. In the latter case, however, the immediate outdoor environment is likely to be substantially more polluted than the area-wide values reported in most ambient air pollution networks. This is due both to the tendency for slums to proliferate near large polluting sources and to the poor local air quality due to combustion of polluting fuels from household, streetside, and neighborhood sources such as small industries (for example, see Ref. 32).

A striking pattern emerges in Figure 3, i.e. that the total human time spent in urban outdoor environments anywhere in the world makes up only about 8% of the total. Nevertheless, this is where the bulk of air pollution monitoring and control efforts have been focused.

Sometime before 2000, a major milestone in human history will be passed, the point when one-half of all person-hours come to be spent in cities.[19] The other one-half will still be spent in indoor and, to a lesser extent,

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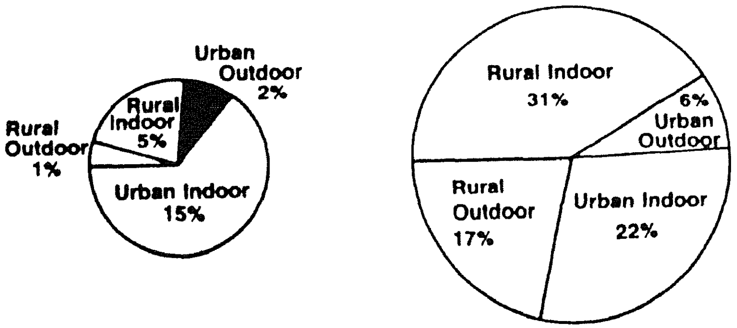
[15] kEU = kilo exposure units = 1000 people breathing 1 μg/m^3 for one year, or 100 people breathing 10 μg/m^3 for one year; or 1000 people breathing 10 μg/m^3 for 0.1 year, etc. This equivalence assumes one-to-one trade-offs among concentration, duration of exposure, and number of people in producing ill-health.

[16] It is necessary to assume a breathing rate to convert from EU to nominal dose. In Figure 2, I used a breathing rate of about 28 m^3/day, a rate at the upper end for adult men. A population mean might be one-half this amount, which would give mainstream cigarette smoke an EE of 2 × 10^5 kEU. If data were available, an even better measure might be nominal dose per unit lung weight, i.e. one that took into account the different breathing rates and body sizes of men, women, and children.

[17] By using the relatively modern tool, receptor-source modeling, in combination with exposure assessment, it is possible to determine the exposure effectiveness of an entire category of sources at once, even without knowing their number or magnitude of emissions (27).

[18] See, however, (28–30).

[19] Based on United Nations Development Program (UNDP) data. By the World Bank's somewhat different criteria of what constitutes "urban," this point was reached about 1990 (7).



DEVELOPED COUNTRIES
(23% of Global Person-hours)

DEVELOPING COUNTRIES
(77% of Global Person-hours)

Figure 3 Approximate distribution of global person-hours in 1990. Note that only 2% lie outdoors in cities of the developed nations where the vast bulk of air pollution monitoring and control efforts have taken place. Data from Table 2

outdoor rural environments, mostly (80%+) in poor parts of the world. The most rapidly growing micro-environments worldwide are those in LDCs, cities, and indoors—which are trends due to three factors:

1. rapid population growth in LDCs;
2. rapid urbanization in LDCs; and
3. a probable shift in daily person-hours from outdoors to indoors when people move from rural to urban life[20] and a slow but relentless reduction (0.7% per year between the mid-1960s and late 1980s) in the proportion of the global workforce in agriculture (33):

Thus, while total human person-hours are growing at 1.7% annually, those in LDCs grow at 2%, those indoors at about 2.5%, and those in LDC cities at 4%.

A reasonable answer to the global question of where the people are might thus be: Most of the people (three-fifths) are indoors in developing countries, of whom the majority are still rural, but rapidly becoming more urban.

From the perspective of LDCs alone, this can be elaborated further as shown in Figure 4. About one-half of LDC person-hours is spent in nations classified as being the least developed, as indicated by the UNDP's Human Development Index (HDI), which is a combination of a nation's income,

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[20] Initially, people moving to urban slums from villages may actually spend more time outdoors or in structures heavily influenced by outdoor conditions.

Table 2 Demographic information related to global distribution of person-hours[a]

Group of nations	Pop/global pop[b]	Urban pop/pop	Workforce pop	Slum dwellers urban pop[c]	Agricultural [illegible] force [illegible]
Developed					
(HDI > 0 9)[d]	23	73	49	1	[illegible]
Developing	77	37	38	33	[illegible]
High-HDI (0 9 > HDI > 0 8)	(5)	75	40	8	[illegible]
Mid-HDI (0 8 > HDI > 0 5)	(34)	42	52	26	[illegible]
Low-HDI (HDI < 0 5)	(38)	28	38	59	[illegible]

[a] Developing countries are classified according to their Human Development Indices (HDI). The derivation [illegible] data are from (33) and refer to the situation in 1990 or the late 1980s. All numbers are percentages of the [illegible] category

[b] Global population in 1990 was 5.28 billion

[c] Used as a surrogate for slum dwelling is the percentage of urban population without access to sanitation. The [illegible] for developing country cities, 31%, is similar to published overall estimates (98)

[d] An HDI of 0 9 is the approximate cutoff between the high-HDI developing nations and the industrialized [illegible] nations

life expectancy, and literacy (33). Although only 28% urban, the annual urban growth rate for this group of 63 nations approaches 5%. This provides the information to answer the somewhat different question of where the most vulnerable people are located.

The most stressed (poorest) populations in the world live mainly (three-quarters) in rural areas, most (three-fifths) of the time indoors, and are participating in rapid urbanization.

Thus, two micro-environments—rural and urban indoors—dominate when looking at the time spent by either the entire LDC population or its most vulnerable subgroups, or when looking at which micro-environment is most important now and which is most rapidly increasing.

Exposure Analysis

The fact that people spend time in particular micro-environments does not by itself indicate a problem unless such places also have significant pollutant concentrations. Here, I examine the evidence for the particulate concentrations[21] in each major world micro-environment to estimate, in turn, the

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[21] Most air pollution authorities recommend that, for health considerations, measurements and control are best focused on the part of the total suspended particulates (TSP) small enough to be inhaled into the deeper parts of the respiratory system. Although conventions differ, in the United States and several other countries, standards have been rewritten for PM-10, i.e. those particles less than 10 µm in diameter. Typically, combustion generates smaller particles, and dust swept up from the ground will have a significant component larger than 10 µm

Table 3 Particulate concentrations and exposures in the 12 major micro-environments of developing countries[a]

Group of nations	Concentrations ($\mu g/m^3$) Indoor	Concentrations ($\mu g/m^3$) Outdoor	Exposures (GEE) Indoor	Exposures (GEE) Outdoor	Total
High-HDI					
Urban	175	110	5	<1	6
Rural	150	70	1	<1	2
Mid-HDI					
Urban	190	300	23	6	29
Rural	400	80	55	5	60
Low-HDI					
Urban	400	280	28	10	38
Rural	700	100	115	11	126
Total			228	33	261

[a] Countries are classified according to their Human Development Indices (HDI), as derived in (33). GEE = global exposure equivalent, which is the equivalent concentration that the entire world's population would have to breathe continuously to equal the population exposure in each micro-environment. For example, the urban indoor concentration of mid-HDI nations (190 $\mu g/m^3$) produces a population exposure equivalent to the entire world continuously breathing 23 $\mu g/m^3$. Urban outdoor concentrations are from (6a). Other concentrations are based on available studies, as discussed in the text. Person-hours spent in each micro-environment are based on Table 2 and Figures 3–4.

human exposures received. Table 3 shows the results for LDCs, divided into the same micro-environments as in Figure 4 (34ab).[22] Table 4, like Figure 3, summarizes the results for the entire world. To put these concentrations into context, Figure 5 reproduces an international comparison of ambient particulate standards done by Ahuja (35). The closest approximation to international standards are the WHO recommendations: no more than 7 days per year when the daily mean is 150–230 $\mu g/m^3$; and an annual mean less than 60–90 $\mu g/m^3$ (36).

URBAN, OUTDOOR For these estimates, I have reorganized the GEMS data set for urban particulate concentrations by HDI groups.[23] The method is shown in Table 5, and the results entered in Tables 3 and 4. Note that unlike the other micro-environments, urban outdoor concentrations do not uniformly decrease with HDI—the peak occurs in the mid-HDI group. This can be attributed to the influence of the Chinese cities with high ambient concentrations found in GEMS, but is probably indicative of a general trend for urban ambient particulate levels to grow at early levels of development and then fall.[24]

URBAN, INDOOR Urban indoor concentrations are substantially influenced by outdoor concentrations as well as indoor sources. Consequently, depending on the kind of household fuels and amount of ETS, they are

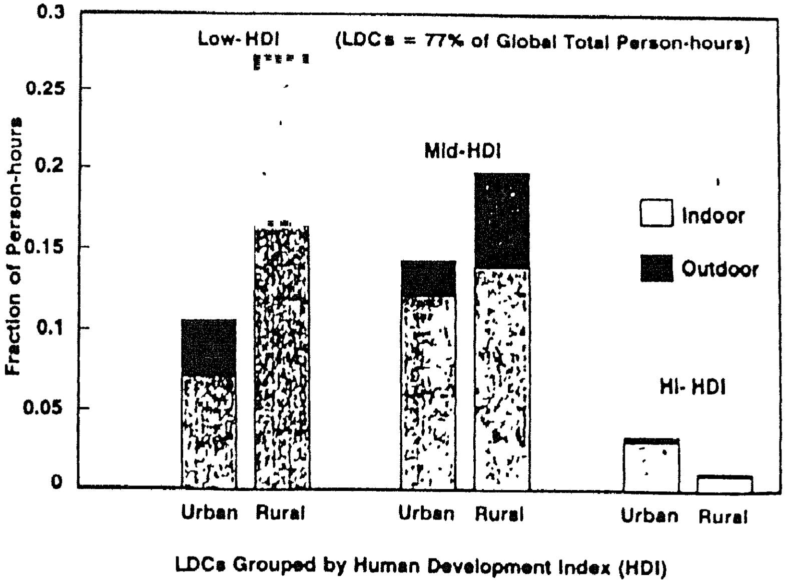

Figure 4 Approximate distribution of LDC person-hours in 1990. The total for LDCs is 77% of the global total (see Figure 3). Note the preponderance of person-hours in the poorest nations. Data from Table 2

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[22] Databases for detailed exposure assessments are becoming available in the developed world (34ab). Until such data are available, LDC assessments, however, can only be done in the rough fashion illustrated here.

[23] For certain developing-country cities, including some participating in the studies listed in the Appendix, there have been monitoring systems in place for some time. If not participating in a quality-control program, such as that required by GEMS, however, the data may not be comparable from one city and nation to another. In recent years, much progress has been made, however, and data quality and quantity are increasing.

[24] In the early 1980s, GEMS broadened its coverage in an attempt to better represent actual ambient exposures by spreading monitoring stations into different sectors of each city. In this way, it was easier to judge whether the outdoor air being monitored was reasonably representative of the outdoor air breathed by the local population (6ab). As the GEMS data set further evolves, it may be worthwhile to make rough estimates of the population represented by each monitoring site in the network and to move or place new stations according to a statistically weighted sampling strategy. Substantial improvements in exposure assessment may thus be attained.

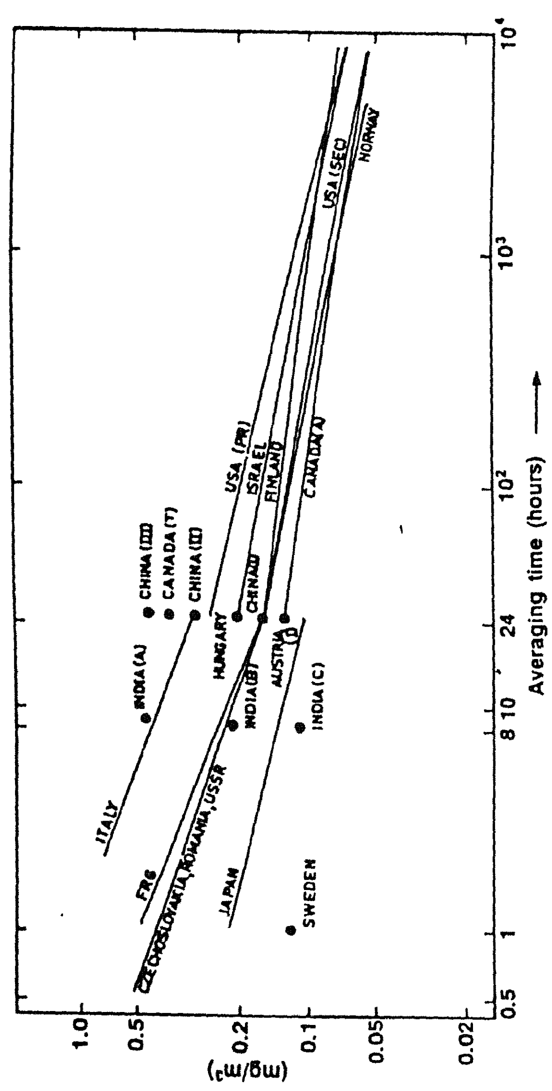

Figure 5 International comparison of air pollution standards for particulates according to averaging time. Increasingly, such standards are coming to be stated in statistical terms, e.g. that there should not be more than 2% of days above a particular concentration per year. Many nations, including the United States, are also promulgating standards for that fraction of particulates less than a specified diameter, usually 10 µm or 2.5 µm. Taken by permission from (35).

Table 4 Particulate concentrations and exposures in the 8 major human micro environments[a]

Group of nations	Concentrations ($\mu g/m^3$)		Exposures (GEE)		
	Indoor	Outdoor	Indoor	Outdoor	Total
Developed					
Urban	100	70	15	1	16
Rural	60	40	3	<1	3
Developing					
Urban	255	278	55	19	74
Rural	551	93	176	15	191
Total			249	36	285

[a] GEE = global exposure equivalent, which is the equivalent annual concentration to which the entire world population would have to be exposed to equal the population exposure in that particular micro-environment. For example, the concentration experienced indoors in developed-country cities (100 $\mu g/m^3$) results in a population exposure equivalent to the entire world breathing 15 $\mu g/m^3$ continuously. Urban outdoor concentrations are derived from (6a). Developing-country data aggregated from Table 1.

often as high or higher than outdoor levels, even in developed countries (37).[25]

Biomass fuels are commonly used in many LDC urban settings, particularly in South Asia and Southeast Asia (38). Most Chinese urban households use coal, although not always in unvented appliances. Many urban households in Africa use charcoal, which while having high carbon monoxide emissions, has substantially lower particulate emissions than does wood. Table 6 gives an idea of the concentrations found in urban Chinese households, where most LDC monitoring studies have been done.

RURAL, INDOOR Although many people think of air pollution as an outdoor urban phenomenon, some of the highest concentrations occur in the inverse situation, i.e. rural and indoors. Such levels are due to the high proportion of rural LDC populations relying on unprocessed biomass fuels (wood, crop residues, dung), which have high pollutant emission factors, in simple small-scale combustion devices, such as household cooking/heating stoves (39). In addition, coal is burned in unvented appliances in many scores of millions of rural households, mainly in China (40). A further large number, particularly in South Asia, use kerosene, which also has fairly high particulate emission factors in inexpensive stoves (41). All of the above fuels have such high emission factors that many tropical homes have high indoor

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[25] See, for example, the data and exposure estimates compiled by Sinton (37).

Table 5 Urban outdoor particulate concentrations by development level[a]

Development level	Nation/city	Stations[b]	Annual concentration ($\mu g/m^3$)
Developed			
(HDI > 0.9)	Australia/Melbourne, Sydney	2CCC, SI	70
	Belgium/Brussels	CCC	
	Canada/Hamilton, Montreal, Toronto, Vancouver	SI, 4CCC, 3SR, CCR	
	Denmark	CCC, SI	
	Finland/Helsinki	CCC	
	Germany/Frankfurt	CCC	
	Greece/Athens	CCC	
	Japan/Osaka, Tokyo	2CCC, 2SR	
	Hong Kong	—	
	USA/Birmingham, Chicago, Fairfield, Harris Co., Houston, New York	2CCR, CCI, SI, 3SR, CCC	
Developing			
High-HDI			
(0.9 > HDI > 0.8)	Malaysia/Kuala Lumpur	SC, SI	110
	Portugal/Lisbon	CCR, SR	
	Yugoslavia/Zagreb	CCC, SR	
Mid-HDI			
(0.8 > HDI > 0.5)	Brazil/São Paulo	—	300
	China/Beijing, Guangzhou Shanghai, Shenyang, Xian	5CCC, 5CCR	
	Philippines/Davao, Manila	2SI	
	Thailand/Bangkok	SI, SR	
Low-HDI			
(<0.5)	Ghana/Accra	SI, SR	280
	India/Bombay, Calcutta, Delhi	3CCC, SR, CCR	
	Indonesia/Jakarta	CCR, SI	
	Pakistan/Lahore	SR	

[a] Data reports were taken in 1983–1986 or 1987–1990 (6a, b). Human Development Indices (HDI) are from UNDP (11). Note that the annual averages were derived by taking the mean of all reporting stations in all cities of each HDI class.

[b] CCC, city center commercial, CCR = city center residential, CCI, city center industrial SC = suburban commercial SR = suburban residential, SI = suburban industrial

Table 6 Indoor coal smoke in Chinese urban households (typical levels)[a]

City(ies), year	Sample characteristics	Typical smoke level ($\mu g/m^3$)[b]
Hebei, 1982	4 times/day, 1 day in summer, 3 days in winter, stoves with/without flue and space-heating compared, housing types compared	500–1800
Hefei, Anhui, 1986	2 months, kitchen/bedroom compared	480–550
Harbin, Heilong, Jiang, 1989	3 days of continuous sampling	390–1030 (R)
Shanghai, 1984	1 time/day, 7 AM–7 PM; 3 cooking periods included, 1 m from stove in kitchen; different ventilation compared	390–2800 340–2700 (R)
Anhui, 1990	Stoves with flue compared with those without flue/bad ventilation; housing type considered; 5 months	690–880
Shanghai, Wuhan, Chengde, Shengyang, 1990	24 hours, 2 days each home, summer/winter average; bedrooms only	270
Lanzhou, Gansu, 1991	Summer/winter, 3 times/day, 5 days; average of 3 housing types	700–900

[a] Source (40)

[b] R = respirable particles only

concentrations in spite of being relatively well-ventilated. Even in village homes using the main clean fuel, liquefied petroleum gas (LPG), ETS is increasing in many countries. Although by no means well characterized, a number of village indoor measurements are now available, as summarized in Table 7. Some of these focus on the cooking time only, when indoor concentrations can be expected to be highest. Increasingly, however, 24-hour measurements are also available. In these studies, indoor concentrations range from a few hundred to a few thousand micrograms per cubic meter ($\mu g/m^3$).

The proportion of the rural population using biofuel in general and poor-quality biofuel in particular decreases with development. This trend implies that the highest particulate concentrations will be found in the nations with low HDI.[26] This category encompasses some 90% of the rural households in India, which makes up three-fifths of the low-HDI group (42). The rural households of mid-HDI nations still use substantial biofuels,

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[26] This need not represent the average daily concentration, but just that during the time when people are present, which is of course when most of the pollution is generated, e.g. from smoking, cooking and heating

Table 7 Indoor air pollution from biomass combustion in LDCs (majority of published studies)[a]

Country, year(s)	Sample characteristics	Typical pollution level (μg/m³)[b]
Papua New Guinea		
1968	overnight at floor level	140–1200
1974	overnight at sitting level	200–4900
Kenya		
1971/2	overnight—highlands	2700–7900
	—lowlands	300–1500
1988	24 hours—thatched roof	1300 (R)
	—iron roof	1500
India		
1982	cooking, 15 mins.—wood	15,800
	—dung	18,300
	—charcoal	5500
1988	cooking—(0.7 m to ceiling)	4000–21,000
Nepal		
1986	cooking—2 hours	4700
China		
1987	all day—wood	2600 (R)
The Gambia		
1988	24 hours—dry season	2000 (R)
	—wet season	2100 (R)
Zimbabwe		
1990	cooking, 2 hours	1300 (R)
Brazil		
1992	cooking—2–3 hours	1100 (R)
	—stoves with flues	90 (R)
Guatemala		
1993	24 hours, 44 homes; stoves—traditional	1200
	—improved	530

[a] Sources: (39, 63)
[b] R = respirable particles only

including those two-thirds of this group that live in China where, as shown in Table 8, many rural households also burn coal (43). Even the relatively small fraction of the world's population in the rural areas of high-HDI LDCs still use some biofuel, e.g. three-quarters of the rural households of the largest nation in this group, Mexico (44).

Rural indoor micro-environments in developed countries, on the other hand, are influenced less by cooking fuels than by ETS and heating stoves.

Table 8 Indoor coal smoke in Chinese rural households (typical levels)[a]

Location, year	Sample characteristics	Typical coal smoke level (μg m⁻³)[b]
Huang, Shandong, 1986	brick bed used, bedroom	620–950
(Suburb) Shanghai, 1987	kitchen	490
Xuan Wei, Yunnan, 1987	4 hrs, 2 days, 1.5 m from fire	25,800
Xinli Village, Jilin, 1987	24 hrs, 5 months, new and old houses, Korean nationality	1200–1700 1000–1200 (R)
Gansu, 1989	2 times/day, 3 days; room center, breathing zone (1.5 m); herders' houses, animal dung also used in same village	1900–5100
Mongolia, Inner, 1990	2 times/day, summer/winter	500–1700 400–1560 (R)
Henan, Xiangshan, 1990	3 times/day; 1.5 hrs average Unvented outdoor	1200 330

[a] Source (40)
[b] R = respirable particles only

Even relatively sophisticated vented wood-heating stoves, as well as fireplaces, are often found to produce modest indoor concentrations (45).

RURAL, OUTDOOR Generally free of large combustion sources, rural areas of both developed and developing countries seem to be relatively clean except, perhaps, during those few days per year that large-scale agricultural burning is undertaken. Exceptions are village environments influenced by emissions from local households, especially in continental areas with ground-level atmospheric inversions (46), something more likely of concern in the lower-HDI groups. Air pollution from household wood-burning (heating) stoves in rural communities is not unknown in developed countries, however. A number of communities in the United States, for example, have found the need to enforce even stricter emission controls than the federal limits, or outright bans of wood-burning stoves.

Trends During Development

Recognizing the limitations of the databases, it is nevertheless instructive to examine the trend of air pollution with development as seen in Figure 6. Note that urban ambient concentrations seem to peak with nations in the mid-HDI group, a trend noted by the World Bank (7) and sometimes

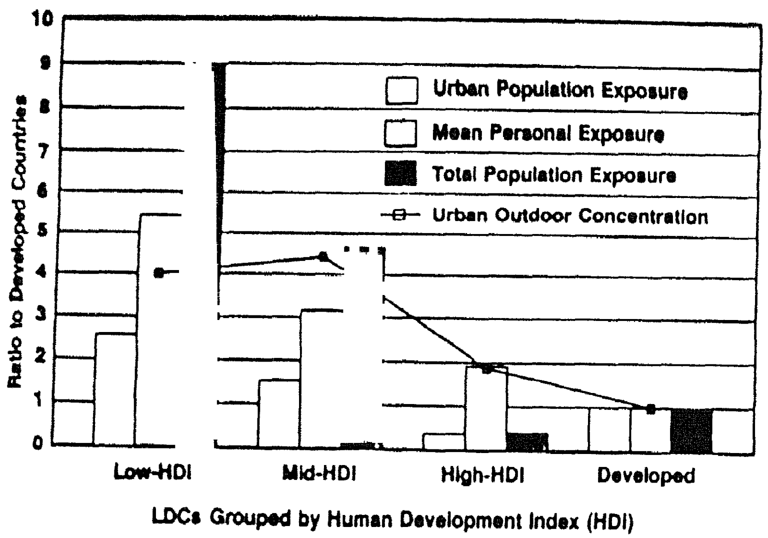

Figure 6 Trends of particulate exposures and urban concentrations by development class. Note that there seems to be a peak in urban concentrations in the middle development class. Average personal exposures, however, decline with every increase in development level. Because of its relatively small population, the highest development class of LDCs actually contains less total population exposure than do rich countries, even though average personal exposure is higher Calculated from Tables 3–4.

generalized to total exposure.[27] In reality, however, personal exposure, i.e. the exposure received by the average person, consistently declines with development. This is also true for urban dwellers alone, as shown in the figure. In contrast, the exposures of high-income LDC urbanites, who may experience little indoor pollution, could conceivably track outdoor concentrations.

Total urban population exposure is highest among low-HDI nations, with a dip among high-HDI nations. This dip is due to the rather small population in this development stage, as seen by the population data in Table 2. Nations seem to move through this phase rather quickly from developing to developed status. The result is that few are found at this stage at any time, a

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[27] On a country basis, Saflick & Bandyopadhyay ("Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence," World Bank Background Paper for (7)) found a quadratic relationship in which urban ambient TSP concentrations started to decrease at about $3300 (gross national product—GNP) per capita The 10% difference between the GEMS grouped results for mid-HDI and low-HDI cities is probably not statistically significant, however. Urban outdoor concentrations are significantly ($p < 0.001$) correlated with HDI at an r^2 of O 6.

phenomenon that is part of Brown's (47) "fissioning of human society" (48).[28]

HEALTH EFFECTS

With the assumptions as stated, Table 4 reveals that the bulk (four-fifths) of world population exposure to particulates occurs indoors in developing countries.[29] Consequently, it is there that we should look first for health effects (49–51).[30]

Rural Indoor Exposures

The high exposures received indoors from solid fuels have been associated with four major categories of ill-health (52):

1. Respiratory infections in young children;
2. Adverse pregnancy outcomes for women exposed during pregnancy,
3. Chronic lung diseases and associated heart disease in adults; and
4. Cancer.

ACUTE RESPIRATORY INFECTIONS (ARI) IN CHILDREN ARI, as pneumonia, is the chief killer of young children worldwide, the vast majority of whom are in LDCs. ARI kills 4.3 million children per year, or 30% more than are killed by diarrhea, the second-greatest killer (53). ARI is also responsible for more episodes of illness than any other disease category. It is well known to be enhanced by exposures to urban air pollutants and indoor environmental tobacco smoke (ETS) at particulate levels some 10–30 times less than typically found in village homes (54).

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[28] A modern version of this phenomenon can be seen in the figures for energy use presented by (48).

[29] Throughout this discussion, linearity between population exposures and personal exposures is assumed. Since ill-health is the concern, this approach implicitly assumes a linear (dose-response) relationship between total exposure and significant health impact Given the many other uncertainties, this assumption probably does not bias the results for most exposure rates considered here (Smoking is a clear exception, however, for the equivalent exposure-rates are many orders of magnitude higher than produced by even the worst air pollution—well beyond the range over which linear dose-response can be assumed.) With sufficient data, nonlinear relationships could be applied, for example, to count only those exposures above some threshold, perhaps US standards or WHO guidelines Doing so, however, would emphasize LDC indoor levels even more, for the exposure rates are also highest in these micro-environments

[30] For useful reviews, see (49, 50) It should be noted that many of the health studies done to date have relied on ambient concentrations as an indicator of exposure, which may have resulted in misclassification of exposures and incorrect risk estimates (51, 51a)

The first published study of woodsmoke and ARI in young children was based on examinations of 150 infants coming to a hospital in South Africa (55). Twice as many children with ARI symptoms than without lived in homes with woodfires. One study that focused on school-age children in Malaysia found no relationship with use of a woodstove, but did find increased prevalence of symptoms with ETS and use of mosquito coils (56). This negative result is similar to that of an earlier study in Papua New Guinea that also worked with school-age children, who have much lower rates of serious ARI than children under 5 years old (57). The only ARI study that actually measured air pollution levels in the same households was in Kenya, but unfortunately it only had resources to examine 36 households (58). High levels of pollutants were found in all houses, with little variation, and, thus, it was not surprising that no association with ARI rates was found.

The most interesting studies now available were done in Nepal, Zimbabwe, and Gambia. The Nepal study examined about 240 rural children under 2 years of age, weekly over 6 months, for ARI incidence and severity (59). A strong relationship between the maternally reported number of hours per day the children stayed by the fire and the incidence of moderate and severe ARI cases was found.[31]

In Zimbabwe, 244 children under 3-years-old reporting to a hospital with lower respiratory disease were compared to 500 similar children reporting to a well-baby clinic (60). Compared to stoves using such modern fuels as kerosene and LPG, woodstoves were more likely to be reported at the homes of ill children. Pollution monitoring showed kitchen particle concentrations to be four times higher in a sample of the homes of ill children than in a sample of the homes of well children. Overall, the risk of ARI was increased by a statistically significant factor of more than two for children living in homes where cooking was done on an open biomass-stove. In a study of 500 children in Gambia, girls under 5 years of age carried on their mother's back during cooking (in smoky cooking huts) were found to have six times more risk of ARI, a substantially higher risk factor than parental smoking (61). Oddly, there was no significant risk for young boys, perhaps because they tended to be carried for shorter periods than their sisters. For infants, however, the relative risk for boys and girls together was almost three (62). In this study, the investigators were able to make mathematical adjustments in their risk estimates to reduce the chance that the risks they found were due to some other factors, such as ethnic group, socioeconomic status, nutritional status, and so on. Separate particulate monitoring in the same region confirmed high smoke concentrations.

As shown in Table 9, these studies indicate that the relative risk for severe ARI from smoke exposures in young children might be in the range of 2–6 (63). Uncertainty remains because, except for the Gambian study, the studies were not able to correct for possible confounding factors such as parental smoking and socioeconomic status.

ADVERSE PREGNANCY OUTCOMES A common problem in developing countries, low birthweight brings on a number of health problems in early infancy. It, as well as other adverse pregnancy outcomes such as neonatal death, has several risk factors, most notably poor nutrition. Since active smoking is known to be a risk factor and ETS exposure also seems to be, there is cause to think the biomass smoke might be as well, since it has many of the same pollutants. Under particular suspicion is carbon monoxide, which studies in Guatemala (64) and India (65) found to enter the blood in women cooking with biomass in substantial amounts. Another study in India found that pregnant women who cook over open biomass stoves had almost a 50% greater chance of stillbirth, although there was no measurable increase in neonatal death rates (66).

Table 9 Acute respiratory infections and indoor biomass smoke (published LDC studies)[a]

Country, year	Sample characteristics[b]	Odds ratio[c]
South Africa, 1982	case-control, infants, n = 150, hospitalized ALRI	4.8 (1.7–14)
Nepal, 1989	cohort, infants, n = 250, + 1 hour/day near fire, dose-response; relationship found for moderate and severe cases but not in older children	2.2 (1.6–3.0)
Kenya, 1990	cohort, 0–59 mo., n = 73, no difference in ARI or pollution levels among house types	n.s.
The Gambia, 1989	cohort, infants, n = 280, exposed on mother's back during cooking, reported breathlessness, adjusted for confounders	2.8 (1.3–6.1)
The Gambia, 1991	same as above; 0–59 mo., n = 587	6.0 girls (1.1–34) n.s. boys
Zimbabwe, 1990	case-control, 1–35 mo., n = 744, hospitalized ALRI	2.2 (1.4–3.3)

[a] Sources (58–63)
[b] n = sample size, ALRI = acute lower respitory disease
[c] Odds ratio is the estimated relative risk of ARI in the exposed group compared to the unexposed group. The numbers in parentheses are the 95% confidence intervals. n.s. = not significant

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[31] Maternal reporting without independent verification, unfortunately, could be affected by recall or other biases.

CHRONIC OBSTRUCTIVE LUNG DISEASE (COLD) AND COR PULMONALE COLD, for which tobacco smoking is the major risk factor remaining in developed countries, is known to be an outcome of chronic air pollution exposure, but is difficult to study because the exposures that cause the ill-health occur many years before the symptoms are seen. Nevertheless, studies in Papua New Guinea, India, and Nepal have led the investigators to conclude that nonsmoking women who have cooked on biomass stoves for many years exhibit higher prevalence of this condition than might be expected or than appear in other women who have used biomass stoves less. Indeed, in rural Nepal nearly 15% of nonsmoking women (20 years and older) had chronic bronchitis, a high rate for nonsmokers (67). COLD has also been associated with long-term exposure to indoor coal smoke in China (68).

Several studies have also found a relationship between reduced lung function, particularly in nonsmoking women, and indicators of indoor pollution from biomass or coal (68).

Cor pulmonale (heart disease secondary to chronic lung disease) has been found to be prevalent and to develop earlier than average in nonsmoking women who cook with biomass in India and Nepal (39).

CANCER Many chemicals in biomass smoke are known to cause cancer in laboratory animals and are found in mixtures known to cause cancer in humans (69). Many of the most potent, such as the polyaromatic hydrocarbons, are carried with the particulate matter. In the 1970s, based on a small study in Kenya, it was thought that nasopharyngeal cancer might be associated with biomass smoke, but newer studies in Malaysia and Hong Kong have failed to confirm this (33). Lung cancer, which, based on risk extrapolations from animal studies, might be expected to be common in biomass-using areas, is relatively rare (70). Indeed, some of the lowest lung cancer rates in the world are found in rural nonsmoking women in developing countries. This is somewhat of an anomaly and can be only partly explained by poor health records. One study in Japan (71), on the other hand, found women who reported cooking with straw or wood fuel when they were 30-years-old to have an 80% increased chance of having lung cancer in later life. (Cancer, like chronic lung disease, takes many years to develop after exposure.)

On the other hand, there is mounting evidence of the lung cancer risk imposed by coal smoke. In a classic environmental health study, for example, extremely high coal smoke exposures in the 1970s and earlier have been linked to substantially elevated lung cancer risks today in rural China (72).

Urban Indoor Exposures

Although there is significant use of wood and other dirty fuels in LDC cities, it is the coal stoves of China that produce much of the total global exposure (Table 8) in this category and have been the focus of most health research. Although there have been studies of other respiratory diseases and even such conditions as stroke, the most striking results from the Chinese studies are those regarding lung cancer (73).

Xiao & Xu (74) found a statistically significant correlation (r = 0.7) between latitude and women's lung cancer rates in 16 Chinese cities. For men, the correlation was smaller (r = 0.2) and not statistically significant. Neither gender showed a trend with latitude for bladder cancer, not usually associated with air pollution. In addition, the men/women ratio declined with latitude, reaching levels as low as anywhere else in the world even though the men/women smoking ratio was high. Among other possibilities (smoking, diet, respiratory infections, outdoor air pollution), the latitudinal, gender, and cancer-site patterns in China are most consistent with indoor air pollution from coal heating as a risk factor (75).

Although it is difficult to establish the decades-long personal histories needed for determining relevant exposures, as shown in Figure 7, the weight of nearly a dozen studies indicates a significant lung cancer risk, 2–6 for urban women cooking/heating for long periods with coal as compared to those using gas. Rural coal smoke exposures, which have been higher, seem to produce higher risks, even to the extent that nonsmoking women have risks similar to those experienced by smokers (76). There are also intriguing indications that the risk may vary substantially by type of coal and with the type of vegetable oil used to fry foods (73).

Urban Outdoor Exposures

Although the urban outdoors has by far the smallest total exposure of the micro-environments (Table 4), more epidemiological studies have been done for this micro-environment than any other, most in developed countries. The value of these studies is greater, however, than indicated by the fraction of total exposure occurring there (less than 1%), partly because there have been so few in other micro-environments that it has been necessary to extrapolate until more specific studies are done.

Fundamentally, these studies looked at health effects resulting from air pollution exposure and used ambient levels as a surrogate for total exposures. The best took account of the cause of the largest difference between ambient and actual exposures, active smoking, a profound confounder for any air-pollution health study. Examples are the classic studies in New York and London, which formed much of the evidence used to set US standards and WHO guidelines in the 1970s.

That outdoor concentrations are an indicator of total exposure, which is dominated by indoor concentrations, is not in dispute, since outdoor air infiltrates indoors (and vice versa). The question is how good an indicator is it? The answer depends on the tightness of the housing and the type and number of local sources. In a developed country where there are relatively few dirty local sources, ambient levels are a much better indicator than in LDC cities, which typically contain a range of dirty household, neighborhood, and streetside sources.

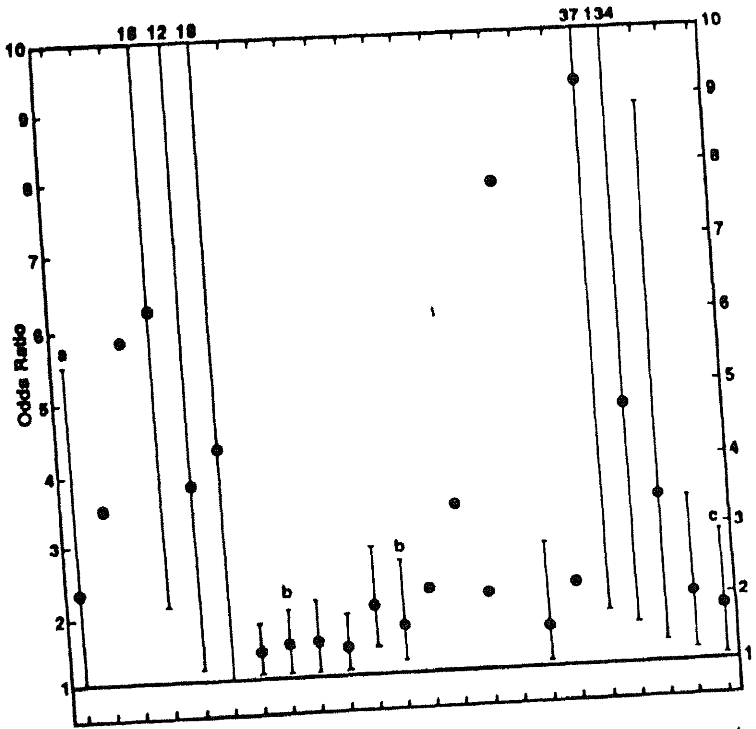

Figure 7 Summary of coal smoke and lung cancer studies. The points represent the best estimates of the odds ratios for each exposure indicator. The lines above and below most points indicate the 95% confidence intervals. By convention, odds ratios for which the 95% confidence interval does not cross 1.0 are termed statistically significant. Except for the first (*a*), which is a study of people in Los Angeles who had been exposed to coal heating in their childhood, and the two marked (*b*), which are from a study that found a relationship between cooking with rapeseed oil and lung cancer, and the last (*c*), which is a Japanese study of women who cooked with wood when they were 30 years old, all of the points represent studies of coal smoke exposures in China. Data taken from (73).

In recent years, with the growing concern about TEA, developed-country air-pollution epidemiological studies are now expected to take into account as much as possible the local conditions that might lead to a difference between ambient levels and total exposure (77). ETS and heating/cooking fuel types are examples. Ongoing now are large studies that actually monitor total exposure itself (78).

TOTAL SUSPENDED PARTICULATES Although TSP has been studied longer than any other outdoor air contaminant, it has been hard to distinguish its effects from those of sulfur oxides, which have usually accompanied it in the developed-country cities where these studies were done. Thus, standards for the two pollutants have often been linked together, as they are in the WHO recommendations (36). In recent years, however, new studies (79, 80) and re-evaluations of old ones using advanced statistical techniques (81, 82) have tended to confirm TSP rather than sulfur oxides as the principal bad actor (83)[32] (84, 85).

Of particular relevance to LDC issues is that these studies have tended to show effects on daily mortality at concentrations at or even below the WHO guidelines for TSP; in other words, no threshold is evident. In addition, at least at the lower end of the dose-response curve, there is a significant increase in mortality even with comparatively small increases in ambient concentration, for example, 6% (86), 7% (87), and 4% (88) increases with a 100 $\mu g/m^3$ increase in ambient levels in three separate US studies. The exact meaning of these studies for LDC conditions is clouded because of different populations, different pollutant mixtures, and a different relationship between ambient levels and total exposure (because of different housing and mix of local sources). Nevertheless, given the relatively high concentrations experienced indoors and out in many LDC situations, health effects could be expected, although the dose-response curve may become less steep at higher exposures, i.e. there may be less additional ill-health per additional 100 $\mu g/m^3$ at 1000 $\mu g/m^3$ than at 100 $\mu g/m^3$.

There have been relatively few air-pollution epidemiological studies in LDC cities. (See, however, Refs. 88a and 88b.) One of the most extensive, a four-year set of prospective studies starting in 1977 addressing the relationship of air pollution, diet, and smoking with mortality and various causes of morbidity, was conducted among four Bombay populations living in differently polluted areas and totaling about 4000 people (89ab). It found a relationship between particulate levels measured outdoors in the neighborhoods of each of the study groups, and various breathing problems, cough, and common colds. Certain causes of death, cardio-respiratory and cancer, seemed to be related to pollution levels as well. Although not able to take advantage of the more recent exposure assessment techniques and multivariate statistical methods, which correct for confounding variables, this pioneering effort is important because it seems to show that a substantial burden of ill-health may be associated with urban air pollution levels of 200–400 $\mu g/m^3$, levels commonly found in LDC cities (90).[33]

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[32] Other studies have shown, however, that there are even stronger relationships between ill-health and more specific measures of particulate size (84) and composition (85).

CONCLUSION

If these epidemiologically elicited dose-response relationships, along with the exposure assessments presented above (Tables 3–4), were to be accepted as reasonable, if rough, first approximations, it would be possible to derive quantitative estimates of the ill-health due to LDC air pollution exposures. To do so for LDCs as a whole with present information is premature, but such estimates could certainly be generated for some local areas.

A principal reason for the relative lack of LDC monitoring data, particularly in time series, is that developing countries are addressing the problem at much earlier levels of economic development than did the presently developed countries.[34] This results in other disadvantages as well as some advantages for developing countries today.

The chief disadvantage, of course, is that they are significantly more handicapped by resource constraints than were the currently developed countries in the 1950s and later when they began promoting major environmental legislation. Another disadvantage for LDCs today is that they are subject to what has been termed "risk overlap." They face not only growing air pollution from industry and automobiles that exert what might be called "modern air pollution risks," but also are still experiencing hazard from the "traditional air pollution risks" of dirty household fuels. LDCs thus must develop a strategy that addresses both traditional and modern risks as they move through the "risk transition" (91).

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[33] There is no space here, unfortunately, to discuss perhaps the most disturbing subcategory of particulate pollution, lead-containing particles in LDC cities (90)

[34] India and China, for example, established their Clean Air Acts in the 1980s with real per capita incomes less than what the United States had a century earlier. Of course the density of population and pollutant sources was much less at that time in the United States

The first advantage held by LDCs is that it is generally cheaper to introduce clean fuels and air-pollution control technologies at the beginning of a growth cycle than to retrofit at a later date. At the same time, with the knowledge about what controls are likely to be desired in the future, provision can be made in long-lived facilities such as power plants to make retrofits less expensive later when they become needed. Putting in the brackets for scrubbers to be added later and reserving the land nearby for storage of the scrubber sludge are examples.

The second advantage is the opportunity to learn from the advances in the technology of monitoring, impacts evaluation, regulation, and control that have resulted from the substantial resources devoted to the problem in many industrial countries. This includes not only new devices, but also such tools as advanced statistical techniques that continue to extract new insights from decades-old air pollution and health data. New, more efficient, regulatory mechanisms, such as emissions trading, have also been developed.

Total exposure assessment is another example of a new method. It leads not only to a realignment in thinking about the relative importance of sources and their impacts on different populations, but also to a broadening of what can be considered as control options. Better ventilation and strategic siting, for example, could have immense exposure-reduction benefits, even if emissions and ambient levels are not much affected. Enhanced fuel quality and combustion at the household and neighborhood levels could well have much more benefit than is reflected by the usual ambient monitoring approach.

LDCs could well take heed of lessons from London's long struggle with air pollution (92).[35] Based on a system of monitoring stations initially established on the tops of fire stations in the 1870s, London took a number of steps to control large outdoor sources during the first half of the 20th century. Success was mixed, however, because of politics, war, recession, and commercial interests. During that same half-century, London was unable to address household sources, mainly coal for space-heating in open hearths, because of political sensitivity to government interference in the domestic sector and a tendency to consider that such small sources could not be important, compared to the obvious large outdoor sources. This all changed dramatically after the infamous London Smog of 1952, during which some 4000 people died prematurely. A great deal of the lethal ground-level pollution came from the average Londoner's hearth. Belatedly, therefore, strong efforts were undertaken to rid the city of all dirty solid fuels.

One of the major innovations in air pollution regulation in recent years has been the development, testing, and implementation of economic instruments. Most outstanding among these has been "emissions trading," which is institutionalized in the 1990 revision of the US Clean Air Act. From an economic standpoint, emissions trading takes into account that various sources have different marginal costs per unit reduction of emissions. This is ignored when uniform controls are imposed, e.g. all coal plants must control to a certain emissions level. Emissions trading allows sources to trade with each other to obtain the same overall control at a lower cost, sometimes a substantially lower cost, e.g. factors of 2–6 (93). Basically, those sources that can reduce emissions cheaply do so first, i.e. there is an incentive for the community of sources to follow a least-cost control curve.

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[35] The first London Air Pollution Commission was set up in 1285, and, after deliberating for 21 years, decided to ban coal burning, an edict that was widely ignored for six centuries (92)

Application of exposure assessment to emissions trading offers the potential for even more economic efficiency. "Exposure trading" refers to the extension of emissions trading in which it is recognized that the marginal damage per unit emissions is also quite different for different sources, i.e. exposure effectiveness varies dramatically (Figure 2). Basically, with exposure trading, emissions would be weighted by their exposure effectiveness, as discussed earlier (94). In this way, a true least-cost pathway could be found for protecting health, as indicated by exposure reduction.

Emissions trading is usually discussed with regard to creation of a government-regulated but private market in tradeable permits. As such, it is sometimes thought that such trading schemes are not suitable for LDCs, which often do not have sufficiently developed markets. Marketability, however, is not essential, although it arguably increases the accuracy and lowers the transaction costs of emissions trading. Top-down "command-and-control" approaches can also apply emissions trading or exposure trading principles. In this case, the government, rather than the owners of the sources, would determine the marginal-cost and marginal-damage functions and apply regulations accordingly.[36]

Exposure-oriented monitoring and exposure effectiveness calculations are not substitutes for ambient monitoring, emissions inventories, and other traditional tools, but, together with them, show high potential to be an important supplement for increasing the speed and efficiency of control strategies. More work is needed, however, to determine how well this potential can be realized in practice; for example, how expensive and burdensome the extra monitoring would be.

As well as giving direction for further research, exposure assessment seems to indicate that the scale of the health impact from indoor air pollution in developing countries may be substantial compared to that from other

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[36] In many LDCs, of course, government-owned facilities such as power plants and steel mills are some of the largest emitters.

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pollution exposures. For this reason, the World Bank has classed indoor air pollution in LDCs among the four most critical global environmental problems, LDC urban air pollution being one of the others.[37] The extent and severity of the apparent impacts on health have important implications for health, energy, housing, and environmental policies in many countries.

APPENDIX: INTERNATIONAL URBAN AIR POLLUTION STUDIES

A number of international studies related to developing-country urban air pollution, as well as other urban environmental problems, have been under way. When the final reports become available, they should provide a substantial amount of new information and thinking about these issues.

1. *Urban Air Pollution in Megacities of the World* (17) is a study done jointly by the United Nations Environment Programme (UNEP) and the World Health Organization (WHO). It examines air pollution in 20 cities with more than 10 million in population (Bangkok, Beijing, Bombay, Buenos Aires, Cairo, Calcutta, Jakarta, Karachi, London, Los Angeles, Moscow, Manila, Mexico City, New Delhi, New York, Rio de Janeiro, São Paulo, Seoul, Shanghai, and Tokyo). Recommendations for urban planners and policy-makers are included (1, 101).
2. *Urban Air Quality Management Strategy (URBAIR)* (2) is a project of the Metropolitan Environment Improvement Program (MEIP) of the World Bank. Through examination of four Asian cities (Bombay, Jakarta, Katmandu, and Manila), URBAIR is preparing guidelines and action plans in support of locally formulated air-quality management strategies. Evaluations of institutional capacities will be an important component, as will organization of baseline weather, air-quality, and emissions information.
3. *Urban Management Program* (99), another World Bank project, is done jointly with UNCHS (Habitat). It is developing rapid environmental assessment techniques for use in developing-country cities and, in collaboration with WHO, is preparing guidelines on managing vehicular air pollution and on city-wide air-pollution control strategies. Jointly with SEI (see below), it is assessing techniques for evaluating household environmental quality that will be tested in Indonesia.
4. *Urban Household Environment Study* (100) is being conducted by the Stockholm Environment Institute (SEI) with partial funding from the Swedish foreign aid agency (SAREC). Air pollution is one of five problem areas covered (102). The study involves 1000 household surveys

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[37] Deforestation and lack of clean water round out the list (7).

in three cities, São Paulo, Accra, and Jakarta, including, in the latter two cities only, 200 household air-pollution surveys. The goals of the study are to support urban environmental management in these cities, to develop methods of more general applicability, and to perform intercity comparisons.

5. *Megacities on the Pacific Rim* (3) is a program of the World Environment Center (WEC), with assistance from the Mansfield Center for Pacific Affairs, and funded partly by the US foreign aid agency (USAID). It has been facilitating the sharing of experience and information among eight cities: Bangkok, Jakarta, Kuala Lumpur, Los Angeles, Manila, Mexico City, Singapore, and Taipei. The initial work focussed on vehicle emissions (102a). The eventual outcome will be a management plan for each city. Under consideration are not only technical and environmental issues, but also economic, institutional, and policy constraints.
6. *Supercities Conference of the Pacific Basin Study Center (PBSC)* (4) was held in late 1992 and included a number of solicited papers on air pollution as well as other urban problems. Special air-pollution case studies were prepared for cities in four countries (Beijing/Harbin, Los Angeles, Mexico City, and Tokyo). To be published in *Atmospheric Environment*, the papers and recommendations of the conference are to serve as the basis for a long-term PBSC research program.
7. *Urban Energy Consumption and Air Pollution Network* (5), funded by the International Development Research Centre (IRDC), Ottawa, has conducted household and transportation energy studies in a number of Asian cities (103). In addition, indoor, outdoor, and personal air-pollution monitoring was undertaken in four cities (Bangkok, Beijing, Manila, and Pune) for the purpose of estimating the changes in exposure that are associated with shifts in urban fuel-use patterns (104).

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Biotechnology: It's Role in Environmental Management

By

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Mass Propagation of Forest Tree Species at TERI's Tissue Culture Pilot Plant

What it's all about

Micropropagation, an essential component of plant biotechnology, is a proven means of producing millions of identical plants by culturing plant tissues or organs under germ-free conditions. The advantages of micropropagation over conventional methods of asexual reproduction are

- greater output
- economy of time and space
- freedom from seasonal constraints
- multiplication under disease-free conditions

This technique is, therefore, ideal for the species where:

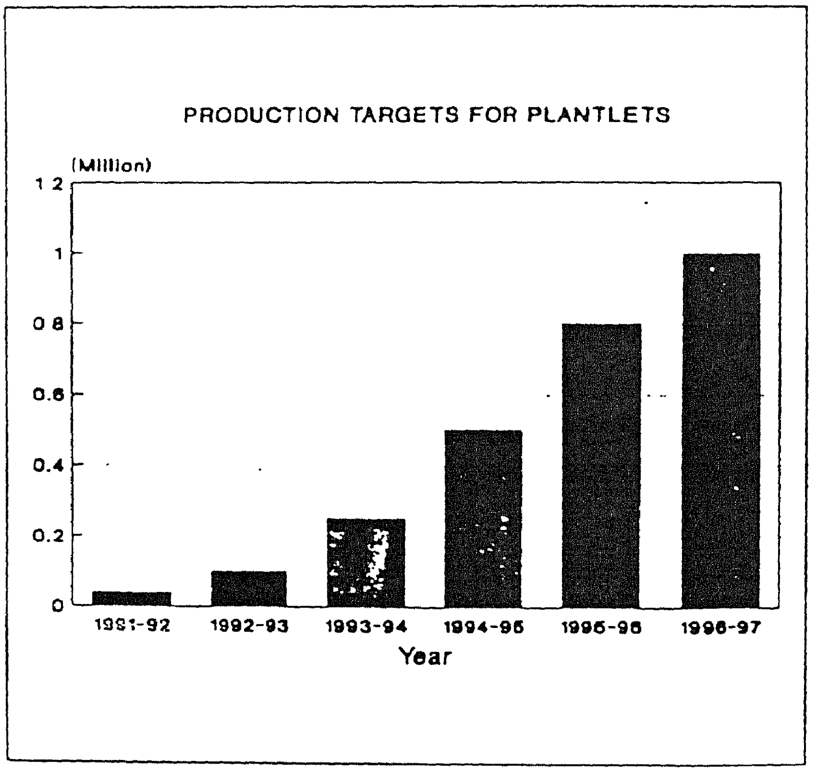
- traditional methods of propagation are inadequate to meet the demand for the planting material
- marked variability exists in the natural population and productivity can be significantly increased by cloning of superior individuals
- virus can be eliminated by culturing the shoot meristem, and pathogen-free stock so generated can be maintained by mass multiplication under sterile conditions.

TCPP: TERI's password to progress

Tissue culture has been successfully employed for the multiplication of orchids and many other ornamental plants. In the developed countries tissue culture is a routine method of multiplication while in developing countries the techniques are largely used for producing plants for markets in the developed part of the world and technology is adapted merely as exploitation of availability of cheap labour.

For tree species, the techniques of tissue culture remained restricted for many years to the laboratory stage and have generally invited only academic interest even in most developed countries. The main factors were recalcitrant nature of most trees - specially in the adult phase when tree can actually be evaluated for the desired traits. Since biomass related problems are of little concern to the developed world, no attempt was made towards commercializing even the available technologies. The Department of Biotechnology (DBT), Government of India, set up two pilot-scale national facilities for large-scale production of elite planting material of forest trees through tissue culture with the objective of bridging the gap between the laboratory and the field and demonstrating feasibility of this technology for forest tree species. One of these facilities is at the Tata Energy Research Institute (TERI), New Delhi, and the other at the National Chemical Laboratory (NCL), Pune.

TERI's Tissue Culture Pilot Plant (TCPP) is situated at TERI's 36 hectare campus at Gual Pahari in Haryana, about 30 km to the south of Delhi. Of an indigenous design, this facility compares favourably with the most sophisticated laboratories in the world, and has an annual production capacity of a million plantlets. Manned by a dedicated team of highly trained young TERI professionals, till date all the production targets set have been successfully met.



The biomass boom

From lab

Research at the TCPP focuses exclusively on developing new protocols for mass cloning of elite tree species, making it one of the very few facilities in the world that use tissue culture for biomass production and increasing land productivity. Some protocols being developed by other R & D projects supported by DBT are also transferred to the TCPP-TERI, for the purpose of modifying/adapting these for large-scale multiplication.

Mass cloning has been undertaken for *Anogeissus pendula*, *Anogeissus latefolia*, Exotic *Acacia* species, *Bambusa tulda*, *Dendrocalamus longispathus*, *Dendrocalamus strictus*, *Eucalyptus tereticornis*, *Leucaena* hybrids and *Populus deltoides*.

Selection of species is made on the following basis.

- Species that have regeneration problems, especially because of poor seed set or germination (as in *Anogeissus* and bamboos). In these cases, seeds collected from the superior trees are used as the initiating material.
- Species that vary markedly in their desirable traits (e.g. *Eucalyptus* and *Populus*) and candidate plus-trees or established clones have been marked from the variant population. These superior trees, identified by the state forest departments, are then multiplied for initial bulking of quality stock.

... To land

Evaluating the plants raised by tissue culture for their performance under field conditions is the most important aspect of work being conducted at the TCPP. This is being done in tandem with forest departments of Haryana, Uttar Pradesh (UP), Rajasthan, Madhya Pradesh (MP) and Bihar. The forest departments of UP and MP are receiving financial assistance from the National Afforestation and Eco-development Board, Ministry of Environment and Forests, Government of India.

For the purpose of initial screening of the identified superior trees, only a few hundred plantlets of the same are raised for preliminary field trials. Only the best clones from these are then mass-multiplied and monitored regularly for performance. During the first year, plants are monitored for mortality on a monthly basis and then onwards data on growth, branching pattern, disease resistance, wood properties, biomass production, and clonal uniformity are collected. Field data indicate a survival percentage of 90—95% in nearly all the cases and a greater height and girth of tissue- culture-raised plants as compared to those raised from seeds.

Since most trees have symbiotic associations, suitable microorganisms (*Rhizobium*/ mycorrhizae) are being explored to ensure better survival in the field after transplantation and increase biomass yield.

On the horizon

The TCPP has established the scientific and process feasibility of large scale micropropagation of tree species. The clonal uniformity of tissue culture produced plants has been well established. Preliminary data indicates that tissue culture plants will give more biomass compared to the open pollinated seed raised progeny of the selected mother trees. The TCPP is in a position to assist the forest departments and other end-users for developing their own facilities and would continue research and production work with other species where tissue culture can be used for conservation of elite germplasm, crop improvement, increasing biomass production, and maintaining and increasing biodiversity.

Number of plants despatched for field trials till May, 1996

Species	**Number of plants**
Anogeissus pendula	3,90,022
Anogeissus latifolia	87,858
Dendrocalamus strictus	55,800
Eucalyptus tereticornis	5,72,215
Populus deltoides	5,78,218
Miscellaneous	11,036
Total	16,95,149

Environmental Rating System
(Background Paper)

By

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1. Background

Facts and figures are being quoted with increasing frequency about the extent of environmental degradation in India. However, there is not much new about the growing concern for environmental issues - it is trend that is over a decade old now. What is new is the socio-economic segments in whom this concern is being felt increasingly. Till a few years back, interest in environmental issues was the domain of 'environmentalists'. Today this realm has expanded to include mainstream segments such as consumers, financiers, managers, corporates.

A couple of factors have facilitated this shift.

- The most basic one is the rising frequency and intensity of environmental problems - catalysed by the rapid industrialisation and urbanisation in recent years. These have brought into focus not only the negative health impacts on human beings and the natural habitat, but also the spectre of resource scarcity, accompanying environmental degradation.
- Following from the above, there is a growing sensitivity to environmental problems, resulting in judicial activism and frequent public interest litigation against Govt. and corporate bodies. These have the potential to not only hurt corporate reputation, but also disrupt business operations in a major way.
- Globalisation is exposing an increasing number of corporates to the more stringent environmental standards of the West viz. green criteria applicable to export products. Moreover, in several joint venture collaborations, the foreign partners are particular about the environmental track record of their domestic partners. This brings on an implicit pressure to clean up as well.
- With the growing size of Indian businesses, the number of stakeholders associated with companies has risen sharply. For instance, the investor/ lender base has broadened with the shift from proprietorships/ partnerships to publicly held companies. So have other stakeholder categories such as collaborators (financial and technical), suppliers, consumers, distributors.

- Correspondingly, there is need for greater accountability and transparency in all aspects of business activity, specially where there is an element of risk to any of the stakeholders. Hence, the rise of financial ratings, standardised accounting/ reporting norms, corporate governance (the latest buzzword!) and now - environmental ratings.
- A fact that has been commonly accepted - including by the Govt. - is the poor quality of regulatory and enforcement mechanisms (e.g. PCB compliance checks). This is attributable to a host of factors, the two most significant ones being corruption and poor quality manpower. A need has thus been created for market based mechanisms, which are self-sustaining and not dependent on Govt bodies for their operation.

2. Goals

Given the above background, the proposed exercise is directed towards developing a tool which will use market mechanisms to -

- sensitise disinterested/ unqualified stakeholders to environmental risk considerations
- offer a measure of environmental performance, for sensitised stakeholders
- consequent to the above, introduce accountability and transparency in corporates
- create positive incentives for improving performance beyond compliance.

An analysis of market mechanisms used in various countries revealed that one of the most commonly used methods to introduce transparency/ accountability consists of performance assessments by third parties, accompanied by public disclosure. This typically takes the form of a certification/ labelling/ rating of a company's operations, by a third party. Some examples of such labels/ ratings include the Blue Angel (Germany), Green Seal (USA), Proper Prokasih (Indonesia), ISO 14000. Each of these vary in scope and nature depending on factors such as -

- Stage of life cycle assessed
- A certification versus a scale of performance levels
- How voluntary?

In the Indian context, based on

- feasibility of measurement/ assessment,
- the institutional context, and
- stakeholder behaviour patterns,

a concept was evolved at TERI which is briefly described below.

3. Objective

To develop an indicator/ index of the environmental performance of a company's business operations. The following would characterise this indicator:-

- *Form:* A 'rating', calculated as the weighted average of scores on a set of pre-determined environmental performance parameters, set against a performance scale. A Rating Committee would constitute a part of the assessment process.
- *Scope:* It would primarily assess production processes, with some addressal of backward and forward linkages. The focus would be on indicators representing impact on bio-physical environment - not encompassing socio-economic variables.
- *Purpose*: To condense a host of complex criteria/ observations into an easy-to-use rating, which would enable even technically unqualified stakeholders to assess the eco-friendliness of a company
- *Strategy*: The concept is market based, and would be completely voluntary in nature. In the long run, the rating system should facilitate a shift from "external rule management" to "internal target management".

The project is currently in the model development stage; it is scheduled for implementation by the end of the year.

Environmental Impact Assessment & Management

By

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ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT

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INTRODUCTION

Environmental impact assessment (EIA) is the process in which environmental factors are integrated into project planning and decision making in a way that is consistent with ecologically sustainable development. Best practice EIA identifies environmental risks, lessens conflict by promoting community participation, minimize adverse environmental effects, informs decision makers and helps lay the base for environmental sound projects. EIA has been defined by Jain et al (1977) in a simple yet convincing way as "a study of probable changes in the various socio-economic and bio-physical characteristics and the environment which may result from a proposed or impending action". Heer and Hagerty (1977) define EIA in more precise terms as an activity that aims" in establishing quantitative values for selected parameters which indicate the quality of environment before, during and after an action".

The field of EIA was pioneered in the USA by the formulation of Natural Environmental Policy Act (NEPA) in 1969. Subsequently, a number of developing and developed countries (Wathern P., 1988) have enacted similar legislation at different times, such as Canada in 1973, Australia in 1974, Japan in 1981, and the European communities in 1984, India in 1994 etc. to conduct Environmental Impact Assessment (EIA) and, thus, study the implications involved in legislating the environmental impact policies in their respective regions. A number of methods have been developed by various workers for preparing EIAs. Most of these methods suffer from excessive dependence on subjective judgments and are weak in predicting and quantifying the impact of the project on the environment. The development of computer based modeling techniques shows promise of bridging this existing gap.

THE EIA PROCESS

Although Environmental Impact Assessment (EIA) procedures vary with each country's unique laws and local practices, the following key steps seem generic and public participation should be infused into each, are described. Figure shows a flow diagram of the generic EIA process.

- Project identification and definition
- Screening and determination of clearance level
- Scoping
- Baseline data collection and analysis
- Identification of impact-mitigation measures and monitoring plans
- Circulation and review of EIA report (perhaps in conjunction with a public hearing)
- Publication of EIA report
- Formal approval (with or without conditions)
- Compliance monitoring and impact management

EIA METHODOLOGY

A number of methods have been developed after the inception of NEPA in 1969 that permit evaluation and assessment of impacts. Some of the important methods are discussed below.

Adhoc approaches

Adhoc approaches were the oldest and perhaps the crudest approaches to EIA. These methods provide very little guidance for assessing impacts beyond suggesting broad area impacts like impact on forests, human population, water, wildlife etc. rather than identifying and measuring impacts on specific parameters. Another drawback of adhoc methods was that they rarely addressed secondary impacts.

Checklists

Checklists are a more formalized version of adhoc approaches as specific areas of potential impacts are listed. Checklists are lists of environmental attributes where the evaluator would tick opposite each item whether the proposed project activities will have an adverse, beneficial or no effect on environmental parameter. Although checklists do define more specifically the parameters that are to be evaluated, they are however usually very large, very subjective and impressionistic and provide little guidance that can aid decision making.

Matrix method

The matrix method is attributed to Leopold et.al (1971). This method uses a matrix format to relate project actions and environmental components. The column of the matrix consists of 100 project actions (can be short listed as per requirement) while the rows of the matrix consist of 88 environmental components (can also be changed or short listed as per the project). If a project action is likely to impact an environmental component then the appropriate cell is scored for magnitude and importance of the impact (on an arbitrary scale). A + or - sign is also put to designate the harmful or beneficial nature of the impact.

Row totals of the matrix reflect the total impact of all project actions on one environmental component while the column totals reflect the impact of one project action on all components of the environment. The matrix total gives the total environmental impact. A similar matrix designed by the Central Mine Planning and Development Institute Limited (CMPDIL) India has been used for the assessment of environmental impacts of mining projects in India. The CMPDIL matrix scores environmental impacts on an arbitrary scale where the following scores are assigned:

Appreciable impact	- 1
Significant impact	- 2
Major impact	- 3
Severe impact	- 4

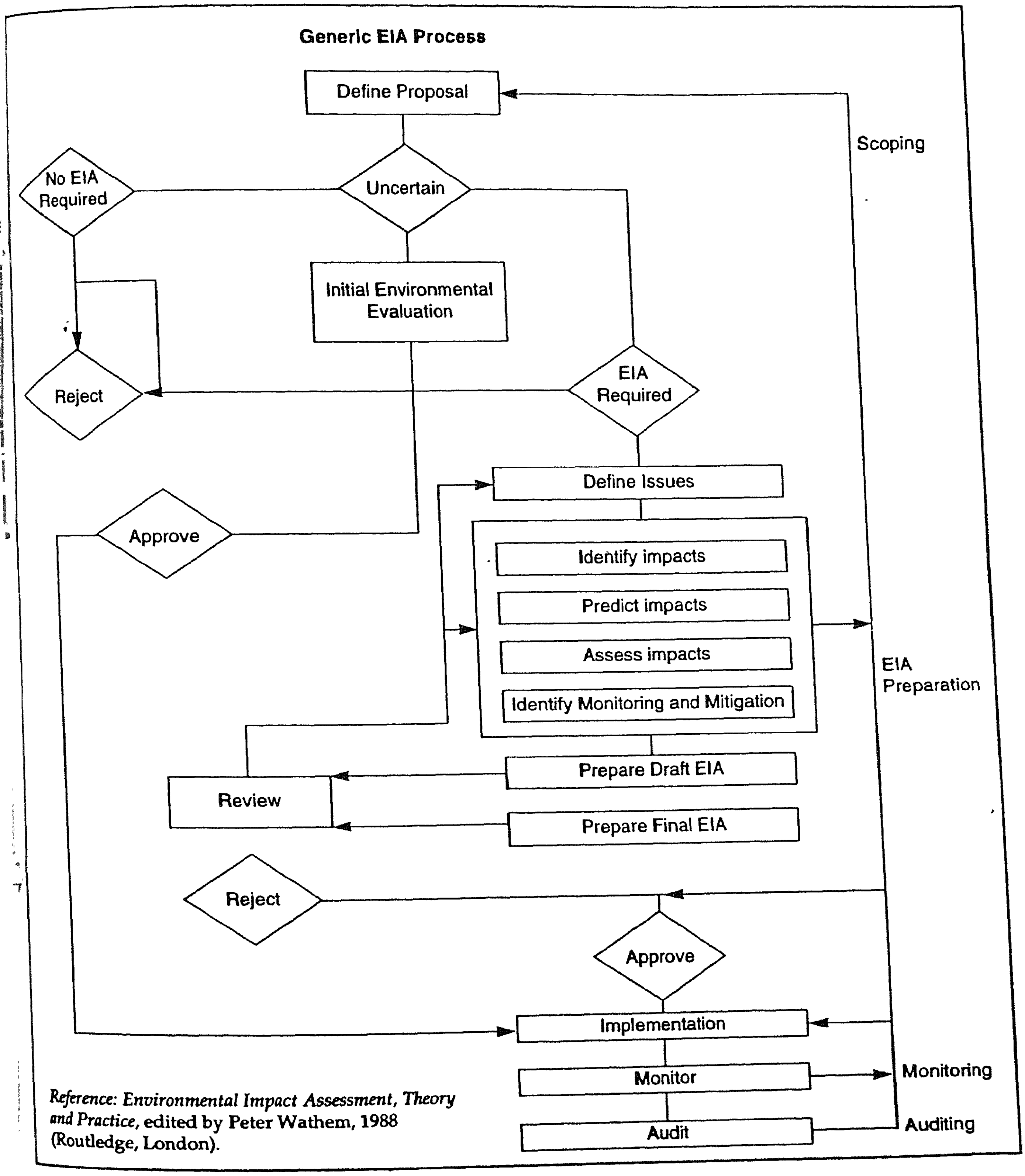
One of the drawbacks of the matrix approach is that it generally does not consider the assessment of secondary impacts. Also, the Leopold matrix is a non-mathematical matrix upon which true algebraic operations (matrix multiplications etc.) cannot be performed. A number of mathematical matrix methods have also been developed that try to address inclusion of secondary impacts and allow true algebraic operations.

Mathematical matrices

The Peterson's Matrix

This matrix was developed by Peterson et al. (1974) and relies on the multiplicative properties

Generic EIA Process



Reference: Environmental Impact Assessment, Theory and Practice, edited by Peter Wathem, 1988 (Routledge, London).

of matrices. The implementation of the Peterson matrix involves the following steps:

a) A matrix is constructed to evaluate the effects of environmental action on the various physical components of the environmental on a ordinal scale of +3 and -3.
b) Another matrix is constructed to evaluate effects of the impacted physical components on human environment.
c) Matrices and developed in steps a and b are then multiplied to give a third matrix that brings out the effect of actions on human environment.
d) The production matrix is operated by a vector of relative weight of human impacts to result in a weighted vector of human impacts.
e) The weighted vector is then summed up to result in a total value of project impact.

This approach has been criticized for too much of mathematical aggregation. Also multiplication of matrices by hand can become very unwieldy and basic inputs to the matrix are still subjective.

Component interaction matrix

Component interaction matrix developed by Ross (1974) is yet another mathematical matrix system that was developed to assess major impacts. Steps involved in the use of CIM are as follows:

1) Construction of a matrix with environmental components on each side and identifying first order dependencies.
2) Matrix is powered to determine all higher order dependencies.
3) A disruption matrix is constructed to score impacts of each project alternatives on all primary dependencies.

Again using this method, matrix manipulation for large matrices is very cumbersome. The minimum link matrix indicates the length and existence of relationship but does not bring out the structure of these chains. The study done by Ross (1974) itself made little use of these matrices in the final analysis. However the CIM does address secondary impacts for which it has received positive reviews.

Network Approach

The objective of network approach is to display in a easily understood format, the intermediary links between projects and its ultimate impacts. Network method aims to work from a list of project activities and establish cause, condition and effect relationship. Since the environmental system is dynamic, an action impacting certain environmental parameter can initiate a series of impacts on a number of other environmental parameters.

Network method primarily addresses this need by defining a set of possible networks and allowing the user to identify impact by selecting and tracing appropriate project actions. Once such trees are constructed they can also be quantified on the following line:

If there are n branches in a impact tree and pi is the probability that impacts on branch I occur

also if M(x) = magnitude of impact x on branch I
and if I(x) = importance rating of impact x

then the impact score for a given branch is = $\sum M(x)\, I(x)$

Environmental impact, EI, for all the branches is given by

$$EI = \sum_{I=1}^{n} pi \text{ (impact score for branch I)}$$

This approach has been reviewed as probably one of the very good approaches for investigating higher order impacts although quantification of impacts is still essentially subjective in nature.

Battlelle Environmental Evaluation System (BEES)

This method is one of the most quantitative and organized methods in EIA. the BEES visualize 78 measurable environmental parameters divided in four major categories of Ecology, environmental pollution, aesthetics and human interest. The employment of this method involves:

1. transformation of parametric estimates into an environmental quality (EQ) scale that ranges between 0 -1 where 0 denotes extremely bad quality and 1, very good quality. This is done using value function curves.
2. multiplication of EQ values with their respective parameter importance unit (PIU) values to obtain commensurate environmental impact units (EIU) for each parameter.
3. aggregation of EIU values for a composite score as follows :

$$EI = \sum_{I=1}^{m} (Vi)_1 \, wi - \sum_{I=1}^{m} (Vi)_2 \, wi$$

where EI, environmental impact

$(Vi)_1$, value in environmental quality of parameter I with project

$(Vi)_2$, value in environmental quality of parameter I without project.

WI, relative weight of parameter I,

m, total number of parameters.

Total environmental impact is calculated by evaluating the expected future condition of the environmental quality with and without the project.

Computer Aided A.

A number of computer aided EA. methods have come up recently. Some of these methods have been designed specifically for special tasks while others are more general in nature one computer system for EA. that has been a trend setting system was developed by the US Army Construction Engineering Research laboratory for predicting environmental impacts of army construction activities. This canopy system consists of three subsystems which are:

1. Environmental Impact Computer System (EICS) identifies potential environmental impacts by relating army activities to environmental attributes. The system also provides mitigation statements specifying common methods and procedures to reduce magnitude of impacts.
2. Economic Impact Forecast System (EIFS) provides quantitative estimates of regional economic impact of army actions based upon an extensive, diverse, interactive database.
3. Computer Aided Environmental Legislative Data System (CELDS) stores abstracts of pertinent environmental legislation. The user specifies his area of interest and the computer itemizes all environmental laws, regulations and standards and pertain to that given area.

Luhar and Khanna (1988) have proposed a computer aided rapid environmental impact assessment system using predictive models for a number of environmental parameters. The method divides the environmental into six broad environmental components (I) namely Air, Water, Land, Biological, Socioeconomic and Noise. Each environmental component above is further divided each into associated risks and control costs (ii) and each risk further divided into measurable environmental parameters and predictors (k). Value function curves have been developed to convert measured values of environmental parameters into environmental quality on a scale between 0 and 1 like the BEES. The overall environmental impact is aggregated using an aggregative index.

A notable highlight of this method is the use of air, water and noise models for prediction of environmental parameters.

Another very popular concept for aiding EA.'s that has recently emerged is that of Geographic Information Systems (GIS) which in the context of EA., can be thought to be computerized versions of the McHargs overlay technique.

Computer based systems however are very expensive to run and maintain and are therefore less frequently encountered inspite of all their merits.

Modelling Approaches

A number of methods that aim to model the environment as a whole by modeling the components and their relationships, inputs to and outputs from the environmental systems have been developed. Notable works include Kane et al (1973) and Holling (1978). Kane et al (1973) developed a mathematical language called KISM. Key features of this approach include the ability to give the non-mathematical experts, capacity to model complex, non-linear feedback systems. Although the authors claim that the system is easy to learn and use and allows for participation of non-mathematical expert panels in model building, derivation of sensible outputs without expert help seem very difficult. The system uses some subjective judgement of impacts but Kane et al (1973) have attempted to justify the use of such scores on the grounds that although they are numerically imprecise, they do contain valuable information that can aid in understanding system interactions.

Holling et at (1978) have formulated an adaptive environmental assessment approach that revolves around the construction of a systems model that is developed through a series of workshops of a team of interdisciplinary experts. A major problem in a modeling approach to decision making is the scaling of judgement. Bandopadhyay et at (1986) have constructed pairwise comparison matrices and then applied Fuzzy set theory to give weightage to different environmental attributes. These methods, however, have not been widely adopted by the industry.

Modeling the environment as a whole is a resource intensive and time consuming procedure which requires a significant level of expertise. For this reason Clark et al (1978) have suggested that environmental impact assessments are more likely to draw on existing models than to create new ones.

A large number of mathematical models are now available in literature for assessment and simulation of a number of environmental attributes like air quality, water quality, noise and behavior of biological systems. Hybrid approaches to EA. using models for prediction of impacts and methods discussed earlier to aggregate environmental scores can provide good objective estimates.

ISSUES IN IMPLEMENTATION OF EA.

A number of problems and constraints that affect the use of EA. as a management tool are as follows (Smith, 1995).

* Regulatory vs Management: EA. is to bc introduced as a regulatory tool to ensure that proponents would include environmental safeguards in their projects.

* Legal Framework: Most informants involved in the EA. process believe that EA. laws are adequate, but that enforcement should be stricter.

* EA. Evaluation Is Too Long: There are no guidelines that specify how long each step in the EA. should take. The average time has been 10 months, and the longest lasted almost 5 years.

* Deficiencies in the Review Process: Several problems adversely affect the review process. There are no guidelines for review. Conflicts of interest may jeopardize the integrity of the process. Non-governmental organizations are not represented on the review panels.

* Lack of Implementation Guidelines: There are no guidelines for project-specified EIAs for scoping, public hearings, multiparty monitoring, the determination and administration of environmental guarantee funds, and projects in environmentally critical areas.

* Baseline Data Lacking: The absence of baseline data increases the cost of an EA., and, in cases where data are available, they are not in a useful form or reliable.

* No Regular Monitoring: Monitoring environmental conditions affected by project operations is the responsibility of project proponents. Most proponents do not submit the required periodic status reports.

* Strengthen Institutional Coordination: Lack of coordination in interagency planning processes also means that EIAs are not properly integrated within each agency. Both types of coordination should be stepped up, and EA. should be integrated with other permitting systems.

* Strengthen Public Participation: Need mechanisms to ensure that all interested parties are participated. In addition, NGOs need training on the technical aspects of EA. to make them effective partners.

* Clarify Funding: The Environmental Guarantee Fund is a well accepted innovation to generate funds to pay for damages caused by or rehabilitation necessitated by a project. Several aspects, however, are not clear - determination of the amount, form (bond, cash, or securities), and administration.

* Specify Criteria: Social acceptability criteria are not clearly specified.

* Role of LGUs Unclear: The role of Local Government Units in the enforcement of EA. needs to be specified.

* Need for Training: There is an urgent need for massive information and education campaigns and training on EIAs.

CONCLUSION

Environmental Management Plans and environmental assessments have used and continue to use highly subjective EA. methods and rely very little on objective scientific experimentation and prediction. These approaches are extremely dificient in the prediction part of the EA. process. It is high time that there should be an increased stress on the development and incorporation of objective and quantitative techniques in environmental assessments in the country. It is felt that formulation of more stringent guidelines than those currently existing for EA.'s is required.

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People's Participation in the Conservation of Biodiversity in India

By

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People's Participation in the Conservation of Biodiversity in India

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Abstract

The paper discusses the tragedy of biodiversity destruction, and points to the fact that this tragedy is more than just ethical, but is critical to certain sectors, particularly agriculture. A review of India's biodiversity is provided, the causes of biodiversity loss in India are analysed, and strategies for conservation identified, particularly government activities. These are judged to generally be inadequate, and a fundamental shift in government and development planning is proposed to empower local communities, and to involve them in the decision-making process.

One aspect of the growing crisis of biodiversity depletion in India is the increasing alienation of people from the very biological resources on which their lives depend. This alienation is due to a variety of factors. The paper identifies these, and discusses them in relation to rural and urban areas and their consequences, and concludes that the solution is to bring people back to centre stage. This means that community control over natural resources be restored; that traditional systems be revived; that the benefits of biodiversity conservation be channelled back to local communities; that the planning and decision-making process be open, democratic and transparent; and that public awareness and education be encouraged.

1. Introduction: The Abundance of Life

Humans are not alone on this Earth, but are just one amongst a large variety of species, a single strand in a vast and complex web of life. Every element of this web, every species, be it a plant, animal or micro-organism, and every link between them, is unique and worthy of respect.

The diversity of life on Earth is awe-inspiring. Although we have named about 1.4 million species to date, the total number of species is estimated to be somewhere between 5 and 50 million. This biodiversity is the very basis of human existence. Food, medicine, clothing, housing, energy, and other material needs are derived from wild and domesticated biological resources, which also provide spiritual and intellectual inspiration. For example, one-fourth of all medical prescriptions dispensed in the USA contain plant extracts, and over half are based on natural products, despite powerful synthetic technologies. In developing nations like India, the majority of people depend on traditional medicines, which are almost entirely based on plant and animal products.

In the midst of this abundance of life, we seem to behave as if we were the only species on earth, and a short-sighted species at that. The scale of human impact on the global environment is so great that we are destroying our own life-support system. Habitat destruction and over-exploitation, pollution, and other human activities have already driven an unknown number of species and ecosystems to extinction. This is especially true in tropical forests, which are being lost at the rate of 17 million ha (170,000 km^2) every year. Since the diversity of plants and other organisms is greatest in such forests, their destruction results in large-scale loss of biodiversity. But tropical forests are not alone, almost every habitat has faced degradation and species loss. The seas, once considered infinite, are suffering from oil and other forms of pollution; freshwater bodies are being drained and contaminated; forests everywhere, including those in temperate countries, are facing the axe, and productive land is threatened by desertification at such a fast rate that one-third of the earth's land surface is threatened. The list is endless.

Though estimates of the rate of biodiversity loss vary greatly, many scientists fear that at least one-fourth of all existing species will be lost over the next few decades. This means that a child today will have a million species less as companions on Earth by the time he or she grows to be an adult. I cannot but consider this a profoundly sad and humbling prospect. What gives us the right to deny others their share of the earth? The decimation of biodiversity is, first and foremost, an ethical issue. Simply because we have the might to eliminate other species does not mean we have the right to do so. Unfortunately, all our principles and laws concerning equality seem to be restricted to our own species.

But the tragedy of biodiversity destruction is more than ethical. It represents the undermining of the resource base of large numbers of people, and the irreversible loss of a potential source of products critical to human welfare. Imagine the human consequences if we had driven the rubber tree to extinction before having discovered its properties. Perhaps a species we are now losing contains a cure for cancer, or will yield a revolutionary new fuel.

The loss of biodiversity is most critical in agriculture. Modern farming practices, including those advocated under the Green Revolution, are eroding genetic diversity in crops and livestock. Most of the world's food now comes from a handful of species and varieties, a situation vastly different from pre-modern times, when any single species or variety would be used by only a handful of communities or people. This recent trend towards uniformity is dangerous, for each pest and disease can now decimate a much larger area of cropped land, or livestock population. Farmers in the USA lost US$1000 million worth of maize crop to a disease which hit genetically uniform varieties, a phenomenon which has been repeated frequently all over the world. Simultaneously, the rapid loss of wild relatives of these crops reduces the chances of finding resistant varieties, or varieties with other desired characteristics. It was one such wild rice variety, found in India, which saved hundreds of thousands of hectares of high-yielding varieties of rice in South and South-East Asia from being decimated by the brown plant-hopper.

2. Biodiversity Conservation in India

2.1 Background

India's biodiversity is one of the most significant in the world. Some 45,000 wild species of 6.5% of the world's known wildlife. Given the fact that a number of biologically rich areas in India, such as the north-east, are not yet fully explored and studied, and given the additional fact that less than 5% of micro-organisms are known, the recorded wild biodiversity is likely to be only a fraction of what may actually exist.

It is not only the sheer diversity which is significant, but also its uniqueness. As many as 33% of all flowering plants and 18% of all plants found in India are believed to be endemic. Exceptional diversity is found in taxa such as ferns (*Pteridophytes*), with 900 recorded species, and orchids, with 1082 species. In the case of fauna, endemism is high among groups such as *Amphibia*, of which 62% of species are believed to be endemic. High diversity is found among butterflies and moths (*Lepidoptera*), with about 13,000 species already recorded, and birds (*Aves*), with over 1200 species.

Equally impressive is the range of domesticated biodiversity. The Indian subcontinent is known as the Hindustan centre of origin of crop and plant diversity, as termed by Russian scientist N.I. Vavilov. At least 166 species of crops and 320 species of wild relatives of crops are known to have originated there. Within each of these species, the diversity of varieties is astounding. For instance, the number of varieties of rice grown in India was recently estimated to be in the order of 50,000 to 60,000, and other crops with rich diversity include wheat, sugarcane, legumes, sesame, eggplant, okra, citrus species, banana, mango, jamun, jute, ginger, turmeric, pepper, cinnamon, and cardamom. Also significant is the indigenous livestock diversity, with 27 breeds of cattle, 40 of sheep, and 22 of goats.

2.2 Erosion of India's Biodiversity

At least 10% of India's recorded wild flora, and possibly a larger fraction of its wild fauna, are threatened, with many on the verge of extinction. This is not surprising, for in the last few decades India has lost at least 50% of its forests, polluted over 70% of its bodies of water, built or cultivated over much of its grasslands, and degraded many coastal areas. To this habitat destruction is added hunting, over-exploitation, pesticide pollution, excessive botanical and zoological collection, and a host of other activities which have taken a heavy toll of biodiversity.

No one can say for sure how many species India has already lost. The cheetah and the pink-headed duck are amongst the few well-known conspicuous species that have become extinct, but there must be hundreds, perhaps thousands, of species which have gone forever, unsung and unrecorded either because they were not "glamorous" enough, or because we simply did not know that they existed. The process continues, as habitats which have scarcely been explored continue to be destroyed. After the shelving of a hydroelectric project in the Silent Valley rain forest in Kerala, several species previously unrecorded in India, and some species never recorded before in the world, were discovered.

A similar tragic fate has befallen India's domesticated flora and fauna. Perhaps the greatest factor in the disappearance of thousands of varieties of crops has been the spread of modern chemical-based agriculture. A handful of high-yield variety seeds have replaced countless indigenous varieties. This is most evident in crops such as rice. The broad genetic base of this crop, mentioned above, provided insurance against pests and diseases, and a bank for desired characteristics like nutritional value and fodder potential in residues. Perhaps equally important, these varieties were culturally valuable; thus in a single village in central or north-eastern India, a rice variety would be grown for its scent, another for its taste, yet another for its colour (red or black being considered sacred), and so on. How can a *striking phenomenon of the Green Revolution*

2.3 Strategies for the Conservation of Biodiversity

Clearly, this erosion in wild and domesticated biodiversity must be halted. This calls for a fundamental shift in development planning, towards a model which respects both nature and culture, which empowers local communities to participate in decisions regarding the use of natural resources, and which is based on the twin principles of sustainability and equity. Forest management and control mechanisms need to be changed to protect and encourage biodiversity conservation and use by local communities. Agricultural strategies must be altered to conserve and enhance diversity in traditional crop and livestock varieties, and to move away from dependence on harmful chemicals and towards organic inputs. Such changes are needed in every sector of the economy.

Today in India there are a multitude of government programmes meant to conserve biological resources, run by specialised institutes and agencies: networks of national parks and sanctuaries, reserves, protected forests and biosphere reserves. Other prominent projects aim at saving endangered species, such as Project Tiger, Project Hangul, and the very recent Project Elephant. There is also an expanding network of *ex situ* conservation attempts, including botanical and zoological gardens and genebanks. For example, the National Bureau of Plant, Animal, and Fish Genetic Resources, under the Indian Council of Agricultural Research, have been undertaking extensive collections and the preservation of germplasm of domesticated biodiversity.

In addition, attempts have been made to give biodiversity conservation some legal sanction. The Wildlife (Protection) Act of 1972 is only one of several relevant laws. A recent assessment by the Indian Institute of Public Administration of central acts shows that at least 20 such acts, and perhaps a few hundred state laws, are relevant to biodiversity. However, while some aspects of conservation are well covered by law, other aspects, such as domesticated biodiversity conservation, are still inadequately covered.

2.4 Problems in Conservation

Important as these government initiatives are, they remain woefully inadequate, as is clear from the continued erosion of biodiversity. One basic problem is that there is very little understanding of what is to be conserved, especially with regard to complex natural ecosystems like tropical rain forests. Conservation attempts continue to be oriented towards the visible or the glamorous; thus emphasis is on the tiger, the rhino, the orchid and the Siberian crane, with little attention to overall biodiversity conservation. In addition, while forests have received a great deal of attention, other ecosystems, such as grasslands and marine wetlands, have been relatively neglected. These weaknesses are being addressed, but will take much unlearning and fresh learning.

Resources to protect and manage natural ecosystems remain sadly inadequate. Staff at the local level, such as forest guards, work under dangerous and impoverished conditions, in which they are no match for the far better organised and well-equipped poachers. A national study by the Indian Institute of Public Administration recently found that, while state governments have been almost eager in declaring a plethora of protected areas, they have hardly ever put their money into management.

local people who, in their day to day existence, interact with biological resources: forest dwellers, fisherfolk, peasants, artisans, nomads and other pastoralists. There has been no recognition or understanding of such people's relationship to biodiversity, their knowledge and techniques, their philosophy, and the critical importance of biodiversity in their lives. For example, the nearly 500 national parks and sanctuaries in India have so far taken a top-down approach, in which wildlife officials almost never interact with local populations. In many cases, rights or other customary claims have been taken away without any provision of acceptable alternatives, and wildlife is being protected by guns and guards. It is quite natural that local communities, in consequence, have turned hostile and sometimes violent.

It is becoming clear now that this is not only a violation of civil rights, but is also self-defeating, for no protected area can survive for long in a hostile social environment. Witness what has happened recently: forest fires and other widespread ecological damage set off by villagers in Binsar Sanctuary (Uttar Pradesh), Nagarahole National Park (Karnataka), Bharatpur National Park (Rajasthan), and other areas where wildlife has been protected *from* the people, rather than *with* the people. The demand to declassify protected areas is increasingly coming not only from groups with vested interests, who are eyeing the lucrative resources of these areas, but also from local communities who have been adversely affected; the Gujjar uprising in the proposed Rajaji National Park (Uttar Pradesh) and the tribal protests in Bhimashankar Sanctuary (Maharashtra) are examples. The elitist approach which has created such conflicts will need to change, and sincere and extensive efforts are needed to win back the confidence and the support of local communities. If they are not to benefit from, and be involved in, wildlife conservation, then such programmes will not succeed. To achieve this, the roots of people's alienation need to be analysed.

3. Alienation of People from their Natural Resource Base

One aspect of the growing crisis in biodiversity depletion in India is the increasing alienation of people from the very biological resources on which their lives depend. This alienation is due to the variety of factors discussed below.

3.1 Rural Areas

In rural areas, increasing state take-over of commonly held or managed resources (forests, land, water) continues the British usurpation of large tracts of forest during the 19th century. Today, the private sector has also joined in, often with help from the state, as for instance bamboo forests taken over by the government for use by private paper mills. Such take-over has also been carried out in the name of biodiversity conservation, as in the case of national parks and sanctuaries, often with a similar result in alienating the local communities.

Increasing commercialisation of resources has led to appropriation by outsiders and greater outflow from rural areas. This is also likely to happen now, for instance, with the "discovery" of the properties of the Indian neem tree (*Azadirachta indica*) as a "wonder plant". Likewise, increasing incursion into private or household functions and activities, and growing dependence on the market (e.g. in basic health care and agricultural operations) has alienated people. Cultural changes, often due to "integration" into the "mainstream", have increasingly come to mean modern wasteful lifestyles, standardised diet, and clothing habits that deplete biodiversity.

3.2 Urban Areas

People living in urban areas are increasingly distanced from life-sustaining resources. This separation from the production base of commodities such as food, furniture and paper has led to a situation in which most people no longer know where these items come from, how they are made, or who makes them. These synthetic lifestyles are caricatured in advertising slogans that claim such things as *thirst is quenched* by this or that product, that *hunger is killed* by this or that brand of noodles, or that *leisure means satellite television*. This has led to increased alienation, particularly younger people, from natural products and nature, with the result that "nature" becomes an "adventure" only to be indulged in during the holidays. Modern education, with its contempt for traditional knowledge and societies, and its disdain for rural work, completes the alienation of urban youth.

3.3 The Consequences of Alienation

The public, more and more alienated from the natural resource base, has a lesser and lesser stake in its conservation. Thus, on the one hand, needs are increasing, while on the other hand, attempts at conserving resources cannot keep pace.

In rural areas, communities and families sell off their resources (forests, trees, land, livestock) or cease to adequately manage them, therefore becoming knowing or unknowing parties to biodiversity destruction. In urban areas, "integration" into the global economy (read: global consumer market) greatly encourages material consumption which far outstrips the supply capacity of the natural resource base.

The state, burdened with a constitutional duty to protect the environment, struggles against, or often joins, the vested interests which have filled in the vacuum created by the disintegration of traditional common property resource management systems. Led by a vision of development which is obviously unsustainable and inequitable, governments cannot hope to conserve the natural resources under their jurisdiction.

4. The Solution: Bringing People Back to Centre Stage

Clearly, one of the most critical aspects of managing biological resources in India is the need to revive and encourage, in all sections of the public, a stake in conservation. The following are just some of the important steps leading in this direction.

4.1 Community Control over Natural Resources

Since alienation of people from their natural resources was partly achieved by removing their control over these resources, such control must be re-established. Some interesting models which have emerged in recent times include:

- the Van Panchayat (Forest Council) system in the western Uttar Pradesh hills, where local villagers are involved in the protection and management of surrounding forests, with overall co-ordination and control resting with the local administration;
- joint forest management schemes in various parts of the country, in which the Forest Department and local village community structures jointly control and manage forest and plantation areas; and
- the proposed village wildlife sanctuary scheme, suggested for the tribal-owned areas of Nagaland. There is no reason why something along the lines of joint forest management schemes cannot be tried out for wildlife protected areas, where conventional state-run conservation programmes are running into rough weather in the midst of hostile communities

4.2 Reviving Traditional Systems

Several traditional systems have proved useful in conserving natural resources. Indeed, local communities need to be helped to revive, strengthen, or adapt practices of sustainable resource management. Many useful models are available from historical and anthropological studies, or even from communities still practising traditional methods of resource management

The modern scientific sector should overcome its strong prejudice against other forms of knowledge, and traditional skills and practices, for instance in the fields of agriculture and medicine. The concept that the "modern" and "traditional" sectors are complementary should be promoted. In addition, specific traditions relevant to biodiversity should be revived. For instance, the citizen's group Lok Swasthya Parampara Samvardhan Samithi (Coimbatore) is working to revive interest in medicinal plants as used in Ayurvedic and other local health care traditions, and is attempting to set up Medicinal Plant Conservation Units in various parts of India. Another citizen's group in Ahmedabad, the Samvardhan Association for the Propagation of Indigenous Genetic Resources, is attempting to record and encourage the conservation of local crop varieties and livestock breeds. The widespread efforts by international agricultural research centres and by national government institutions to record and preserve genetic resources in *ex situ* collections need to be viewed in the context of such independent citizen's efforts.

4.3 Channelling Benefits of Biodiversity Conservation Back to Local Communities

Biodiversity conservation must increasingly benefit local communities, who are often asked to make sacrifices for such conservation. Again, several models and ideas are available from past and present times.

- Integrating conservation into an overall development strategy for specific regions. Eco-development is, of course, the latest buzz-word in government and foreign aid circles. But the conventional pitfalls of "planning from above" (sometimes more threatening when agencies such as the World Bank are involved), without involving the recipient community at every stage of the decision-making process, must be avoided.
- Ensuring meaningful employment (not just as daily labour) in conservation programmes, especially by utilising traditional skills (e.g. the rickshaw-pullers of Keoladeo Ghana-Bharatpur National Park, who are now prime tourist guides).
- Sharing the benefits from the wider utilisation of genetic resources and knowledge of local communities, for instance in the field of biotechnology. This will require a legal structure in which profits made by outsiders (including the state and private corporations) are shared with the relevant local communities. The mechanisms of this are complex, and need to be worked out.
- Encouraging *in situ* conservation of traditional crops and livestock, by offering economic and other incentives which would make up *for the loss of economic returns from the adoption of more profitable varieties. The slowly growing population of environmentally conscious consumers in cities, who are building citizen's networks with farmers who have adopted traditional crops and organic agriculture, is a promising prospect in this direction.*

Widespread public participation requires that planning and decision-making by governments at all levels becomes open to public scrutiny Specifically, at least the following steps are necessary:

- making all information relevant to biodiversity available to the public, and penalising the wilful withholding of such information,
- establishing a system of public hearings before major decisions are taken, such as the creation of a protected area or the implementation of a development project in a biologically rich area; and
- recognising and respecting the valuable role of mass movements in environment and development related issues. Often these movements do not directly address the conservation of biodiversity, but such recognition is an essential off-shoot of their campaign. Examples are the conservation of marine fisheries as a result of the mass struggles by traditional fisherfolk against trawling, led by the National Fisherfolk Federation and other groups; and the saving of valuable central Indian deciduous forests by mass tribal protest against the proposed Bhopalpatnam and Ichampalli dams.

4.5 Encouraging Public Awareness and Education

While those sectors of the population that most need education in environmental matters are resource-illiterate planners and decision-makers, clearly all sections of the public will benefit from appropriate awareness campaigns To this end, steps could include·

- inclusion of the concept and practices of biodiversity conservation into both formal and informal education. While the environment has increasingly become a component in education through the efforts of hundreds of citizen's groups, biodiversity as a specific topic should now be incorporated;
- the use of folk media, popular science methods and other innovative methods to spread the message of the importance of conservation;
- the publication of advertisements in all major national and regional newspapers and magazines, carrying excerpts of important documents like the Wildlife (Protection) Act, and the Convention on Biological Diversity,
- making available full texts of such documents in all major Indian languages; and
- popularising, through various educational media, innovative traditional and modern methods of conservation.

5. Conclusion

No single government agency, nor the government as a whole, can possibly achieve the task of conserving biodiversity in as complex a society as India's. The participation of people at all levels in the task of managing the country's resources should not only be considered a fundamental right, but also a pre-requisite for successful conservation.

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Climate Change

By

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Climate change negotiations: *an Indian perspective*

1. Introduction

The UN Framework Convention on Climate Change (UNFCCC) was signed in June 1992 in Rio de Janeiro and has been ratified by almost 160 countries. Developments in the last four years and at the second session of the Conference of the Parties (COP-2) indicate that the world is still divided; the scientific community is divided from the political world. In November 1995, the Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change(IPCC), concluded that 'the balance of evidence suggests a discernible human influence on global climate' and that if policies to reduce CO_2 emissions from current levels were not undertaken, the average global surface temperature would rise by 2° C between 1990 and 2100 - an average rate of warming greater than any seen in the last 10,000 years.

As we move into the third session of the Conference of the Parties (COP-3) to be held in Japan in December 1997, some of the contentious issues need to be resolved.

1.1 Science of Climate change

The Second Assessment Report (SAR) of the Intergovernmental Panel on Climate change (IPCC) provides the scientific, technological and economic evidence on the basis of which the Parties to the Framework Convention on Climate Change (FCCC) can negotiate international commitments. The Summary of the Report prepared for Policy makers indicates that:

- Greenhouse gas concentrations have continued to increase.
- The balance of evidence suggests a discernible human influence on global climate.
- Average global surface temperature has increased by about 0.3° C to 0.6° C over the last century with the recent years have been among the warmest since at least 1860.
- Significant 'no regrets' opportunities are available in most countries to reduce emissions of greenhouse gases at no net cost.

and

- The potential risk of damage from climate change is enough to justify action beyond such 'no regrets' measures.

2. Developing country perspective

2.1 Overview

The developed countries have appropriated a significant amount of natural resources in the *past*, subsequently leading to global warming and climate change. The developing countries have not contributed significantly to the problem and in light of the fact that most of them are currently in the process of industrialization would at *present* require the use of these natural resources. Across the globe, every country would require use of these resources in the *future*. What needs to be decided now is who can use how much and in what time frames, given the past, present and future scenarios. An analysis of this would involve past, present and future use of the natural resources[1].

Thus, Article 3.1 states

> *.......protect the climate system for the benefit of present and future generations....on the basis of equity and the common but differentiated responsibility of countries and respective capabilities.*

The developing countries have an acknowledged right to develop in the short-term[2] . A point that gains substantial significance is that despite the claim that countries like India are emerging major energy consumers, this is not entirely true. For example, in the case of per capita coal consumption, the OECD average is 1058 koe, which is much larger than the world average of 394. In comparison, India, has a very low per capita consumption of 132 koe[3].

Further, it must be noted that although per capita emissions of greenhouse gases (GHGs) in developing countries is low, their emissions per unit of GDP are quite high. Hence, there is scope for these countries to develop and in the process increase their GDP, without necessarily having an increase in their GHG emission. Further, developing countries do recognize that mitigation measures in their countries constitute the most economic short term path to GHG reduction with the joint benefit of providing an investment opportunity for long term GHG reductions in their countries, thus avoiding the projected emission scenarios. As stated in the Convention, developing countries would undertake those measures to address climate change within their respective capabilities. In addition, a point that gains significance is that the history of pollution control indicates that it is possible to undertake measures to mitigate pollution only after having reached a certain level of "affluence". Developing countries have more immediate problems realted to survival which, rightly so, recieves higher priority.

While it is true that climate change is not a priority area for the developing countries, some countries have during their development paths pursued energy programme started in earnest in 1982[4]. Today, at over 800 MW of installed wind capacity, the Indian wind energy programme is the third largest in the world, after the US and Germany. Sales of PV modules in India account for about 10 MW of the global total of 80 MW - indicating the dynamic growth of renewable energy technologies within the broad policy environment for their promotion.

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[1] Barathan S. 1997. Emerging trends in global climate change negotiations: a developing country perspective. In Proceedings of the 20th Annual International Conference of the International Association of Energy Economics. Volume I. New Delhi. 1997.

[2] FCCC. 1992. Framework Convention on Climate Change. Rio de-Janeiro. June 1992.

[3] TERI. 1997. UNU-TERI Initiative on the UNFCCC. Background paper. Presented at the UNU-TERI Joint meeting on climate change. January. 1997.

2.2 Concerns

Having provided a brief background on the developing countries, we now move on to discuss some of the key concerns of the developing countries from an Indian perspective. This would need to be analysed under two parts - till Kyoto and beyond Kyoto

Till Kyoto

a. how and when to stabilize climate change
b. new and additional commitments from developing countries
c. economic impact of Annex I commitments on Non-Annex I countries

Beyond Kyoto (in addition to b and c above)
d. inadequacy of technology transfer
e. ineffectiveness of the financing mechanisms

2.2.1 How and when to stabilize climate change

There are many uncertainties in the predictions of global warming particularly in relation to the timing, magnitude and regional patterns of climate change[5]. Uncertainty has been used as a reason for postponing action until there is sufficient information generated to justify action. However, the results of the IPCC SAR indicate that there is enough evidence to show that climate change is an irreversible problem. From this, stems the need for concerted action on the Berlin Mandate.

Consensus continued to elude COP-2 on a number of issues, the most contentious being that of the conclusions of the IPCC SAR. The COP-2 concluded by bringing out the "Geneva Declaration," which endorses the SAR of the IPCC and calls for legally binding objectives and significant reductions in greenhouse gas (GHG) emissions. However, the Declaration did not specify that reductions should be well below the 1990 level set in the FCCC and failed to specify an upper-bound for the stabilisation of climate.

The results of the review of the first national communications of Annex 1 Parties are a matter of concern and the credibility of all Parties was at stake. Fifteen developed countries accounting for 55% of the Greenhouse Gas (GHG) emissions of the group expect emissions levels by the year 2000 to exceed those of 1990.

The basic question is the stabilisation level. There is a need here to highlight that we follow a precautionary principle.

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[4] Venkata Ramana P, Chandra Shekhar Singh. 1995. Renewable energy program in India in Venkata Ramana P and Kozloff K (ed). Renewable Energy Development in India: Analysis of US Policy Experience. TERI, New Delhi.

[5] Houghton J T, Jenkins G J and Ephraums J J. 1990. Climate change: The IPCC Scientific Assessment. Cambridge University Press, Cambridge.

Further, most exercises undertaken to assess the actions and options do not take into account the cost of impacts.

Thus, it is crucial that a legally binding instrument such as a Protocol be adopted at COP-3 which would support strong commitments of Annex I Parties. However, the Protocol should include provisions for allowing amendments to the reduction timetable based on scientific assessments of the IPCC to allow for flexibility. A provision for a schedule of reviews would need to be built into the Protocol. The key elements of the Protocol should include the following:

* A stabilization atmospheric concentration of 450 ppmv of CO_2 should guide the stabilization target.
* Confirmation of 1990 as the base year for emission controls as established in UNFCCC.
* Acceptance of 2005 as the first year for legally binding emission reduction targets. A short term target is essential if climate change policy is to be successful and to pave the way for greater involvement by all Parties, and "showing by doing".
* Inclusion of 10% of 1990 levels as the first reduction target for all Annex I Parties.
* Recognition of per capita as an important basis for targets.
* Designating the Parties to develop their respective technology plans by the year 2000.
* Permitting emission trading between Annex I Parties with appropriate reporting, and monitoring carried out by a central facility.
* Inclusion of provisions for allowing amendments to the reduction timetable based on scientific assessments of the IPCC to allow flexibility **(Reference???)**

2.2.2 New and additional commitments from developing countries

Despite the fact that the Berlin Mandate specifies that the negotiations shall introduce no new commitments for developing countries, there have been efforts on the part of the developed countries to strengthen non-Annex I Party commitments within the context of the FCCC. Climate change is a reality and global warming has already occurred. Impacts are evident in some parts of the globe.

Impacts of global warming will be felt both in the developed countries and in the developing countries. However, the present data does show that the developing countries are more vulnerable to effects of climate change, as their economies are more dependent on climate sensitive sectors, like agriculture and forestry, and they have less technical, institutional and financial capacity to adapt to the effects. As a percentage of income, the welfare losses in the developing countries are expected be several times less than the developed countries, although the quantum of these damages are subject to debate. An estimate is of the range of monetary damage is given in Table 1.

Table 1. Aggregate monetary damage for 2 x CO_2 (annual damages)

Region	Damage	
	in % of GDP	in % of real GDP*
Developed countries (OECD)	1-2%	1-4%
Developing countries & countries with economies in transition	2-9%	0-7%
World	1.5-2%	1-2%

* GDP corrected for differences in purchasing power parity

Source. IPCC 1996

Samuel Frankhauser analyzing the global damage costs, points out that absolute terms it amounts about US $365 to US $485 billion (on the basis of present GDP) and in per capita terms annual cost of around US $500 per OECD citizen. This goes to show that the costs would be very significant (Pearce D W, 1995).

The loss of 1-2% of the GDP for the OECD may be smaller as compared to the developing countries, however, they are very significant in terms of absolute amounts.

With action being postponed by the North and trying to involve the South in new and additional commitments (due to the fact that this bloc may become a major contributor to GHG emissions) a possible scenario is that of developing countries being impacted due to climate change including sea level rise. As a result of which they would focus on "*adaptation measures*" as opposed to "*development measures*" [6].

2.2.3 Economic impact of Annex I commitments on Non-Annex I countries

An issue raised particularly by the oil exporting countries has been that of the economic impact of Annex I commitments on non-Annex I countries. Annex I countries in response to meeting their commitments may undertake certain policies and measures (e.g. imposing efficiency standards). In addition, standards for carbon may be imposed on the imports of energy intensive commodities. If strict restrictions (rigorous standards) are imposed, which restrict the import of such products from the non-Annex I countries, it would affect growth of such industries in the non-Annex I countries, specially if these industries are dependent on the export of the outputs (internationally traded).

2.2.4 Inadequacy of technology transfer

The technological evolution of the last few decades, as experienced by the industrialized world has led to the point where such economic growth warrants an environmental evolution. Without technological transformation which is environmentally compatible, it is most unlikely that economic growth can be ecologically sustained. In light of this, how then are the developing countries going to respond to the challenges? And what is it that must be done to narrow the gap that lies between them and the technologically advanced nations?

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[6] Barathan S. 1997. Emerging trends in global climate change negotiations: a developing country perspective. In Proceedings of the 20th Annual International Conference of the International Association of Energy Economics. Volume I. New Delhi. 1997.

As regards the progress on technology transfer, yet again the developed countries have failed to take concrete steps. The general findings in the note prepared by the Secretariat for the Subsidiary Body for Implementation (SBI) clearly stated that, "a comprehensive picture of technology transfer activities is not available at the present stage"[7]. Subsequently, specific proposals have been tabled with respect to technology transfer. Hence, the legally binding instrument such as a Protocol which would be adopted, hopefully, at COP-3, should require all the Parties to develop their respective technology plans by the year 2000. The developing countries by the means of this plan, should identify the areas where they require assistance in terms of information, technology upgradation, introduction of new technologies, capacity building, financial inputs and removal of barriers to technology transfer both formal and informal. On the other hand, the Annex I Parties can list areas where they have the expertise and capacity to provide assistance to other countries. This would help facilitate effective technology and financial transfers.

The Annex I, as well as the non-Annex I countries should also try and declare their baseline technologies, in order to facilitate calculation of marginal emissions abated during AIJ/JI beyond the pilot phase (with credits) and emissions trading. This would be helpful in ensuring additionality of reduction and avoiding free riders.

2.2.5 Ineffectiveness of the financing mechanisms

While, the FCCC clearly states that the industrialized countries would take the lead and also that they would take the first steps domestically and (a) provide new and additional financial resources to meet agreed full costs in complying with communicating inventories of sources and sinks and mitigation measures, agreed full incremental costs of implementing GHG abatement measures and cost of adaptation of developing countries to the adverse effects of climate change and (b) provide for transfer of relevant technology for developing countries to fulfill their commitments, progress on this front has been far from satisfactory. Of the two financing mechanisms, I would be focus on AIJ, as has been requested.

Global Environment Facility

One of the concerns of the developing countries is the role of GEF. GEF is likely to move towards developing operational programmes. The GEF Operational Strategy places emphasis on solar thermal power generation, photovoltaic applications biomass power technologies, fuel cells and advanced fossil fuel technologies. The operational strategy also supports wind power and micro hydro programmes. It is worthwhile to note that support for power generating technology dominates the GEF operational strategy.

Without underestimating the significance of these technologies, it is important to realize that the needs which dictated their development need not correspond to all the needs of the developing countries. Majority of the R&D efforts in the developed countries is dictated by the desire to displace conventional sources from energy sectors which are important in their context - power generation at a significant scale and transport. In light of the fact that the imperatives of developing countries encompass additional concerns and end-uses, such an endeavor would provide insights into how national priorities could be complemented with global imperatives. As the GEF gains experience in dealing with global environmental issues, it needs to develop long-term operational strategy for technology development for global good. Furthermore, the GEF must help in the institutionalization of systems which facilitate the absorption of environmentally sound technologies[8] .

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[7] FCCC. 1996. Subsidiary Body for Scientific and Technological Advice. Second Session. A Note by the Secretariat. Geneva: FCCC Secretariat.

In addition, the level of funding is very low and there is no evidence of additionality. It only seems to be a shift in the ODA finances.

Activities Implemented Jointly

India is a Party to the Convention and was keen to pursue the AIJ mechanism. It had lent support very early in the discussions on AIJ but had taken the backseat on reviewing the progress/discussions of the Annex I Parties where there have been attempts not to abate domestically. The AIJ mechanism opens a lot of opportunities to develop cooperative agreements for implementing abatement projects. However, there still exist a number of apprehensions and reservations among the developing countries which need to be resolved in order to successfully meet the objectives of the mechanism. The primary one in our case has been the concern that the non-Annex I Parties intended to use this as a mechanism to fulfill their obligations by undertaking measures outside their national boundaries. Further, a point that warrants mention is that the pilot phase is a non-starter.

Other concerns include shifting of responsibility of the Annex I Parties on the non-Annex I countries, may not be consistent with national priorities, the nature of the crediting regime and a reliable, effective and not expensive monitoring system, and verification mechanism.

While there would be a need for *flexibility and a project-by-project eligibility and approval criteria in the pilot phase*, it would be important to recognize the need for certain minimum requirements. These could include:

1. no ODA (overseas development assistance) money should be used to finance AIJ projects;
2. projects should be supplementary to the other efforts for the FCCC, particularly, existing financing mechanisms such as the GEF;
3. project has to be cost-effective and proven to be lower than any action or measure that remains un-implemented in the donor countries. AIJ should not be used to avoid action in the donor countries; and

The issue of the AIJ projects being supplemental and, particularly, to ODA is important; in no way should other projects be financed by ODA be eligible as AIJ projects.

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[8] Pachauri R K et al. 1996. Technology transfer: an agenda for change. Paper presented at the workshop on Stimulating Technological Change: The FCCC in The Context of Developing Country Initiatives held at The Second Session of the Conference of the Parties. 18 July 1996, Geneva. Switzerland.

Credits in AIJ/JI

The AIJ/JI can be viewed as a three-stage process[9]:

Stage 1:	*Pilot phase of AIJ with no credits ever (including no credits for projects implemented in the pilot phase after the conclusion of the pilot phase).*
Stage 2:	*Operational AIJ/JI with credits accruing to investing country (primarily Annex II) parties. In this phase of AIJ/JI there are no commitments to non-Annex I countries other than those currently contained in FCCC, namely, those of the national communications.*
Stage 3:	*Re-negotiated AIJ/JI regime when non-Annex I countries have additional commitments other than current commitments in the FCCC. The re-negotiated AIJ/JI regime would have to ensure that there are no net transfer of resources from non-Annex I countries in the Stage 2 AIJ/JI as a result of the new commitments to non-Annex I Parties.*

3. Conclusions

The fulfillment of the Berlin Mandate by the adoption of a legally binding stringent reduction target for Annex I countries, if it happens, will only be a first step. The guiding premise is simple and straightforward: countries that have been responsible for the problem should now become part of the solution. Without this commitment to take concerted steps and measures to reduce GHGs in order to stabilize the climate, our chances of achieving a future worth having and passing on to future generations are slim to non-existent.

The success of the framework of negotiations would require striking a balance between the concerns of the developing countries and those of the developed world. It is quite crucial that developed countries take the lead in addressing the problem of global warming and climate change, gain credibility by returning to emissions at the 1990 level by 2000, specify that reductions should be well below the 1990 level set in the FCCC, set an upper-bound for the stabilization of climate and take concrete measures to address the concerns of developing countries.

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Montreal Protocol

By

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Ozone Depletion: India and the Montreal Protocol

The **Montreal Protocol for the Phaseout of Substances that Deplete the Ozone Layer** represents the first international commitment to consciously phaseout the use of an entire class of chemical (manmade) substances for the good of the global environment. This commitment is especially notable because the phaseout has to be achieved in a (rather short) specified time period, and involves substantial costs.

This paper examines the evolution of this commitment, together with science and the politics that contributed to it; and India's response to the Montreal Protocol, both in terms of the international negotiations, and the internal policies and procedures for its implementation. The major achievements brought about as a result of the Montreal Protocol process (both internationally, as well as within the country) are also discussed in the perspective of their bearing on other international agreements to protect the global environment.

The Science of Ozone Depletion

In the early seventies, Prof. Francis Rowland at the University of California, Irvine, noted the presence of trace amounts of the manmade chemical, trichlorofluoromethane (CCl_3F), better known as CFC-11 (or Freon-11), in the composition of all air samples throughout the world. This observation presented to him, 'an interesting scientific puzzle' - what will eventually happen to these man-made molecules which have been released into the atmosphere and had spread globally?

Together with a colleague, Dr. Mario Molina, Prof. Rowland initiated the investigation of atmospheric processes that affected CFCs. They calculated that the altitude at which the CFCs (which are very stable molecules) would finally decompose because of their interaction with the UV (ultra violet) rays from sun would be in the stratosphere (15-30 kms above the earth), within the ozone layer that ~~of~~ effectively blocks the UV radiation incident on the earth. As a result of this decomposition, the chlorine in the CFCs would be released in the form of atomic chlorine (which is very reactive), which would, in turn, react with the ozone molecules (O_3) in the ozone layer. As a result, the ozone is decomposed into molecular oxygen (O_2) through the formation of an intermediate chemical species, ClO (see box 1 for the chemistry of CFC-ozone interaction).

These calculations lead Molina and Rowland to predict that the steady release of CFC molecules into the atmosphere would eventually lead to a loss of 7 to 13% of global ozone, and they called for a halt to further emissions of CFCs (Molina and Rowland, 1974: Rowland and Molina 1975)

Outline of CFC-Ozone Interaction Chemistry

The ozone layer is formed because of the reaction of the ultra violet (uV) rays from the sun with oxygen molecules in the atmosphere:

O_2 + UV ----> O + O (1)
O + O_2 + M ----> O_3 + M (2)
O_3 + UV ----> O + O_2 (3)

(The M in reaction (2) symbolizes a third molecule, any molecule, that must be involved in this collision)

The reactions (1) and (3) result in the absorption of UV rays 15-30 kms above the earth; consequently the O_2 - O_3 reactions and the formation of ozone molecules (O_3) prevents UV rays from reaching the earths' surface.

CFC-11 (CCl_3F) and CFC-12 (CCl_2F_2) are very stable compounds that do not normally react and breakdown into their constituent elements in the lower atmosphere - in current environmental terms, they are "non-biodegradable". Consequently, they slowly diffuse through the entire atmosphere, and rise to great altitudes as well. At altitudes above 15 kms, the energy of the UV-rays (particularly the UV-C rays) from the sun is adequate to decompose them:

CCl_3F + UV-C ----> Cl + CCl_2F (4)

CCl_2F_2 + UV-C ----> Cl + $CClF_2$ (5)

The atomic chlorine reacts with the ozone molecules and the atomic oxygen in the ozone layer (which is largely in a band at altitudes between 15 and 30 kms) to form molecular oxygen:

Cl + O_3 ----> ClO + O_2 (6)

ClO + O ----> Cl + O_2 (7)

O + O_3 ----> 2O_2 (8)

Since the usual reaction of O atoms involves the formation of O_3 by (2), the effect of (8) is really equivalent to the removal of **two** ozone molecules. In addition, the atomic chlorine liberated from CFC-decomposition is available again after (7) to decompose another set of ozone molecules. This chain process continues in rapid bursts of ozone removal, and the average number of ozone molecules destroyed by every chlorine atom is eventually about 100,000.

Predictably, their findings lead to an uproar. The link between ozone depletion and increased UV radiation on the earths surface and its deleterious effects on human health, plants, and materials was well known. Consequently, the presence of CFCs at altitudes of 15-30 kms was questioned, as was the proposed chemistry (see box 2) of ozone destruction.

CFCs: the wonder chemicals

It was particularly ironic that the CFCs were found to cause a global environmental problem. CFCs (chlorofluorocarbons) do not exist in nature, and were created, "to specifications". They are chemically inert, and easily converted between gaseous and liquid states at ordinary temperatures. There are three major CFCs - CFC-11, CFC-12, and CFC-113 (CCl_2F CCl F_2). The three-digit numbering nomenclature follows the rule: the first digit is the number of carbon atoms minus one (in case there is one carbon atom, the first digit is zero and is not written); the second digit is the number of hydrogen atoms plus one; and the third digit is the number of fluorine atoms.

CFCs are used as refrigerants in refrigerators and air conditioners; as propellants in aerosol sprays; as foaming agents for blowing foams (for applications in refrigerator insulation, car seats, mattresses, thermoware, etc); and for the cleaning of electronic assemblies.

This versatility in the market-place brought about a steadily increasing demand for CFCs in all countries around the world; CFC use doubled every five to seven years, and approached 1 million tons in 1974 when Molina and Rowland published their hypothesis of CFC-based ozone layer destruction.

An experimental test of the predictions was carried out in 1975 by collecting air samples at different altitudes in the atmosphere through unmanned stratospheric balloon flights sponsored by the US National Academy of Sciences (USNAS). The measured concentrations were in excellent agreement with the predictions of Molina and Rowland (1974).

These tests transformed Prof. Rowland's "interesting scientific puzzle", into a major global environmental problem.

The Effects of Ozone Depletion

The US NAS balloon samples of CFC composition at various altitudes in the atmosphere proved the Rowland-Molina hypothesis relating CFC emissions to ozone depletion. In the years that followed, intensive experimental and analytical research was conducted to measure CFC and ozone concentrations, changes in UV-irradiance, and projected changes due to the continued emissions of CFCs. In the two following sections, the current state of knowledge regarding ozone depletion and impacts of increased UV-radiation are briefly summarized.

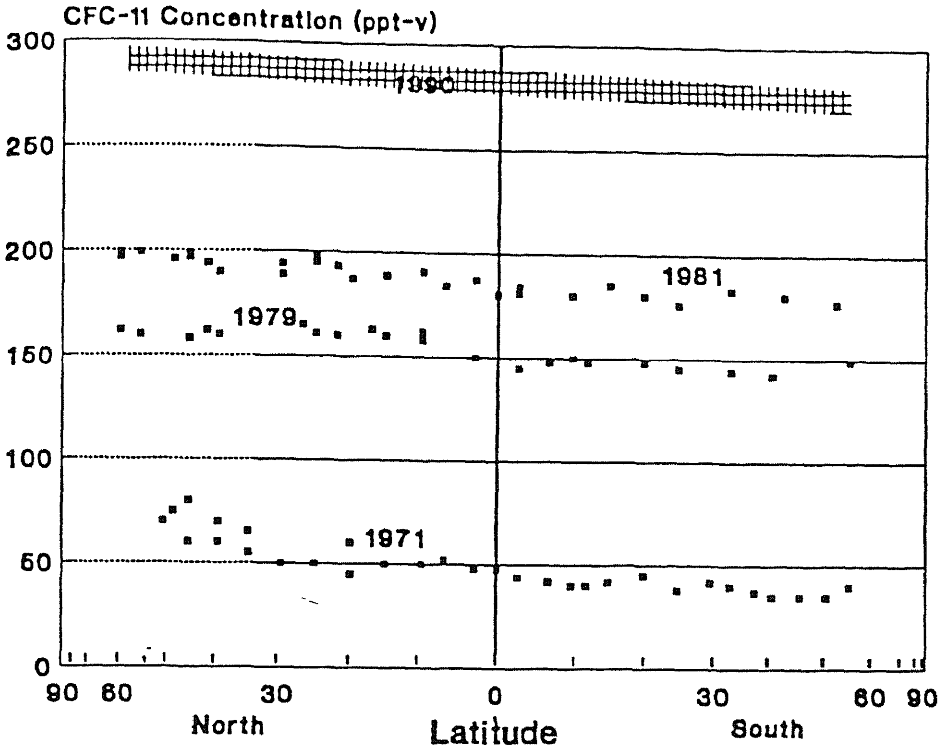
CFC-ozone interactions

Since the first global air-composition measurements which showed the ubiquitous presence of CFCs (Lovelock, 1971), measurements have been carried out regularly. Figure 1 shows the concentrations of CFC-11 in surface air samples at different latitudes in 1971, 1979, 1981 and 1990 (Rowland, 1991).

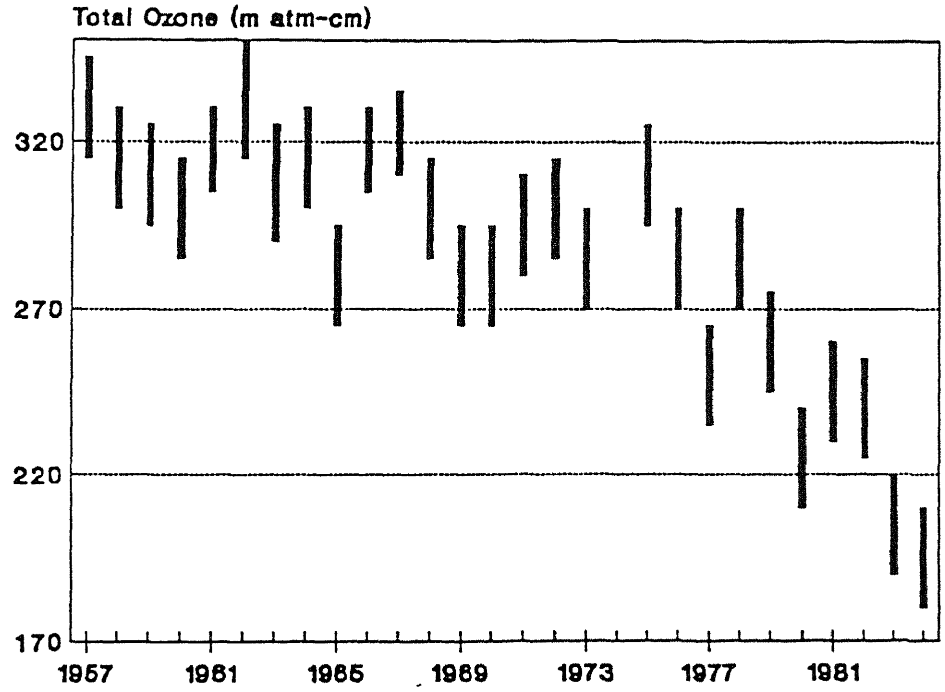
The figure shows that CFC-11 concentration exhibits a North-South gradient. The minimum concentrations are over Antarctica, and have been about 7% lower than the global average. At the same time, the ozone concentration in Antarctica has also been decreasing over the time. Figure 2 shows ozone at Halley Bay, Antarctica, from 1957 to 1984 - the decreasing trend from the mid-seventies is clearly evident.

Based on ozone measurements carried out since 1978 by TOMS (Total Ozone Mapping Spectrometer) abroad the Nimbus 7 satellite, and by ground-based aircraft, the CFC-ozone depletion link has been conclusively proven, particularly by the presence of CFCs and of intermediate chemical species (such as ClO) in the ozone layer. The data also support Figure 1: there is much larger ozone loss in the Southern Hemisphere than in the north. Recently, a similar (through smaller) decrease in ozone levels in the Arctic has also been measured.

The reason for preferential ozone depletion in the polar regions arises because of the very cold temperatures that enhance the formation of PSCs (polar stratospheric clouds, which are condensed forms of ice crystals). The strong circumpolar vortex over Antarctica results in a very high frequency of occurrence of PSCs in that region; much more than in the Arctic. Ozone loss is found to be initiated by chemical reactions on the surface of PSCs which convert the long-lived chlorine into chemically more reactive forms that destroy ozone. This is thought to be aided by the denitrifications reactions that also occur on the surface of the PSCs and remove the nitrogen that could have lead to the reformation of less-reactive chlorine compounds.



igure 1: Concentration of CFC-11 in surface air samples collected at various latitudes.



Source: Farman et al. (1985)

igure 2: Monthly means of total Ozone measured at Halley Bay, Antarctica, for each October from 1957 to 1984.

As a result of ozone depletion, the UV ray intensity at the surface of the earth increases. Figure 3 shows the existing levels of UV radiation at different latitudes, as well as the expected increase due to a decrease in the total ozone at different latitudes (Ilyas, 1989). The percentage increase is much higher at the higher latitudes than at the lower latitudes for equivalent ozone depletion. However, with ozone depletion preferentially occurring in the higher latitudes, the changes are expected to be far greater there than in the tropics since the absolute levels of UV radiation, even after substantial increases, in the higher latitudes will be less than in the tropics. No changes in the ozone or UV radiation over India have been noted as yet (Mani, 1991).

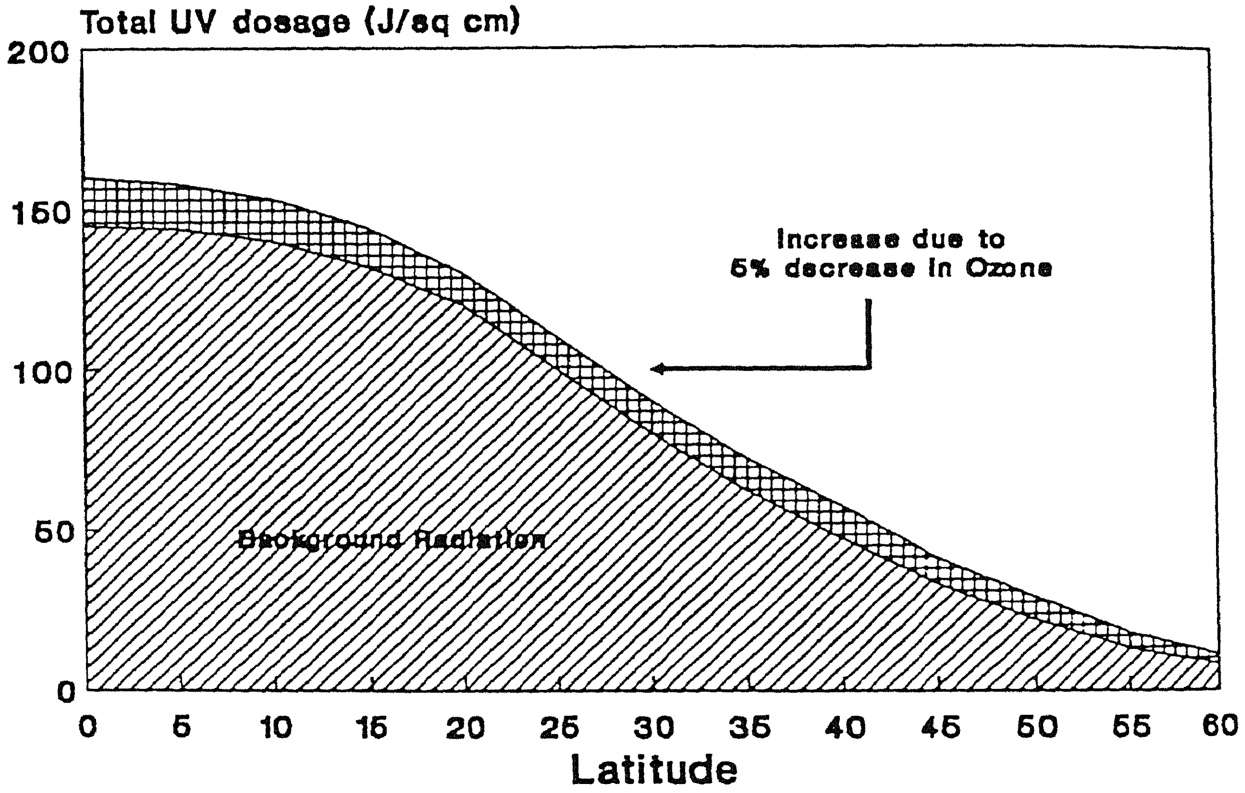


Figure 3: **Background UV radiation and estimated increase due to 5% Ozone depletion.**

The impacts of enhanced UV radiation on earth*

The decrease of ozone molecules in the stratosphere implies that less UV radiation is absorbed by them (reaction (3) in box 1), and consequently more of it reaches the earths' surface. One particular component of the UV radiation, UV-B radiation is of particular importance. With ozone layer depletion, UV-B radiation reaching the ground increases, and its average wavelength shortens. Most effects of UV radiation depend strongly on the wavelength, with the largest impacts associated with the shorter wavelengths. At the wavelengths that UV-B reaches the earths' surface, it has a multitude of effects on humans, animals, plants, and materials. The quantitative nature of many of these impacts is not certain, and is the subject of research presently.

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* This section is based on the UNEP Effects Panel Report (1989)

Human health

In humans, exposure to increased UV-B radiation can lead to suppression of the bodys' immune system which leads to an increase in the occurrence or severity of infectious diseases, and a possible decrease in the effectiveness of vaccination programs.

Enhanced levels of UV-B radiation can lead to increased damage to the eyes, particularly cataracts which are estimated to increase by 0.6% for 1% total ozone depletion. Therefore, in the coming decades, each 1% ozone depletion is predicted to lead to a worldwide increase of 100,000 blind persons due to UV-B induced cataracts.

The other major expected impact on humans is an increase in the incidence of non-melanoma skin cancer. The percentage increase will be much faster than one-to-one: it is expected that every 1% ozone depletion will lead to a 3% rise in the incidence of non-melanoma skin cancer.

Plants

About half of the plant species investigated are found to be sensitive to UV-B radiation, the impact typically leading to reduced growth and smaller leaves. In some cases, these plants also show changes in their chemical composition which affects the quality and availability of mineral nutrients. In certain economically important food species (e.g. soyabeans), increased UV-B radiation corresponding to 25% decrease in total ozone results in a 25% reduction in food yield.

Aquatic ecosystems

Increased UV-B irradiance has been shown to have a negative influence on aquatic organisms, particularly small ones such as phytoplankton, zooplankton, larval crabs and shrimp, juvenile fish, etc. Most of these small organisms are at the base of the marine and global food chain, and increased UV radiation could result in major impact on fisheries productivity.

These are indications that increased UV-B radiation also lead to a decrease in the nitrogen assimilation through prokaryotic micro organisms, and thereby cause possible nitrogen deficiency in rice fields.

Materials damage

Exposure to UV radiation is a significant cause of degradation of many materials, especially plastics. This degradation is found to be enhanced by high temperatures and bright sunshine.

The Politics of the Montreal Protocol

In response to the initial scientific concerns published in 1974 linking CFCs to ozone depletion, some nations quickly banned the use of CFCs as aerosol propellants. This initial phase of regulation, however, led down a blind alley. Only a handful of nations imposed limits on the use of CFCs as aerosol propellants, with the majority adopting a "wait-and-see" attitude. Furthermore, the national regulations that were adopted affected only aerosols and therefore did little to encourage innovation regarding other uses of CFCs. In fact, CFC use increased in the refrigeration, foam and electronics industries throughout this period: because the aerosol ban was mistakenly thought to have solved the problem of ozone depletion, industry shelved its plans to develop CFC substitutes. By 1985, CFC use in the United States had reattained the previous levels reached in the mid-1970s.

The independent national regulations also led to a contentious debate in the mid-1980s regarding a possible international approach to limiting CFCs. With some countries already having taken action while others had not, the early negotiations failed to find a common point of departure. Further actions to limit CFCs on a use-specific basis proved especially problematic. Who was to decide which uses of CFCs were essential - high quality perfume in Paris, or automobile air conditioners in Washington, DC?

Several years of difficult negotiations made it clear that limits on specific uses of CFCs would not provide a workable basis for an international agreement. Only through the concept of production cutbacks, combined with the increased scientific consensus regarding the causes and effects of stratospheric ozone depletion, was progress around the negotiating table possible. Even then, the resulting 1985 Vienna Convention on the protection of the Ozone Layer was only a framework agreement that by itself would do little to prevent further ozone depletion.

By the mid-eighties, scientific studies had concluded that increasing emissions of CFCs would irreparably damage the ozone layer. In 1985, there was a starting announcement of a substantial loss of stratospheric ozone over Antarctica (Farman et al, 1985). This loss occurred during the Austral spring and had been noted every year since 1977 (Figure 2).

Consequently in September 1987, a number of countries met in Montreal, Canada, to sign the Montreal Protocol on Substances that Deplete the Ozone Layer. The Protocol did not take effect immediately, however, because at least 11 countries representing at least two-thirds of world consumption were required to ratify.

Towards the end of 1988, a sufficient number of countries had signed the Vienna Convention and the Montreal Protocol to allow it to come into force.

The early years of the protocol

Unlike previous national limits on the uses of ozone-depleting chemicals, the Montreal Protocol dealt directly with the production of these chemicals. This agreement required nations who join to restrict their production and import of eight primary ozone-depleting chemicals. As it was originally formulated, the Protocol froze production and consumption of five CFCs at 1986 levels by 1989, reduced them to 80% of 1986 levels by 1993, and to 50% of those levels by 1998. Production and consumption of three halons was to be frozen at 1986 levels by 1992.

By limiting CFCs at their point of production, the Montreal Protocol ensured a reduction in the amount of pollutants generated. In doing so, it also avoided the problems of selecting individual uses to control, of establishing emission limits for each use, and of monitoring and enforcing across all uses.

Several countries soon adopted measures to further reduce the use of CFCs. In June 1988, the Swedish Parliament passed legislation that included specific deadlines for the complete phase-out of CFCs in new products, with consumption halved by 1991 and virtually eliminated by 1995. Austria announced its plan to reduce its consumption of CFCs by 50% in 1991. Australia proposed a 95% reduction of CFC use by 1995 and a full phase-out by 1998, and Norway introduced a broad initiative that, with some exceptions, eliminated all consumption of CFCs by 1991.

While some use-specific restrictions have been implemented on a national basis by many of these countries, these actions have been taken within the framework of an international agreement that deals specifically with the production and consumption limits.

Voluntary agreements with user-industries also played a significant role in several nation's strategies to reduce the use of CFCs and halons. In several countries, including Finland, Mexico and Egypt, use reductions were supported by voluntary agreements with specific user industries. The European Community negotiated voluntary agreements with the refrigeration and foam sectors. In West Germany and the Netherlands, industry voluntarily agreed to phase-out CFCs as much as possible by 1995. In the United States, the food-pack aging industry has virtually eliminated CFC use in manufacturing foam products by shifting to alternative blowing agents, and the fire-protection industry has announced voluntary reductions in halon emissions during testing procedures and other unnecessary uses of halons.

Recycling is another pollution prevention strategy that became a priority among many nations seeking to reduce CFC emissions. Austria and Norway proposed requirements to recycle or recapture and destroy all CFCs used in refrigerators and air conditioners when serviced or discarded. Local governments in West Australia and some Canadian provinces controlled emissions through recycling in their jurisdiction. Several states in the US passed laws governing recycling and recapture of CFCs, and the EPA has developed a national recycling programme.

An excise tax passed by the U.S. Congress on the sale of ozone-depleting chemicals in 1989 also aided CFC recycling in the US by increasing the costs of virgin controlled substances. As CFCs become more scarce, the incentive for both producers and users to recycle has increased. Because of the higher cost of virgin CFCs, both due to scarcity and because of the excise tax, the payback period for capital invested in recycling equipment was reduced. Furthermore, the excise tax exempted the resale of chemicals that are recycled. Recycling the controlled substances, instead of buying virgin chemicals, lowered the costs of doing business for users.

The tax on ozone-depleting substances also created a market for substitute chemicals. Because substitutes cost more than CFCs, no market for these alternatives could exist without higher CFC costs. The tax, in addition to the limited supply of CFCs, increased the cost to users and thus sent the needed signal to the marketplace to shift to alternatives.

The developing countries and the montreal protocol

During the discussions leading to the formulation of the Montreal Protocol, several developing countries made the point that the use of CFCs and halons was ultimately connected with development. Their use in many modern services and amenities, such as aerosol sprays, foam insulation and cushioning, cleaning of computer chips, and especially in refrigeration and air-conditioning, makes then an essential component of the industrialization occurring in the developing countries. In many of these countries, large investments had been made in projects based on CFC utilization, and the developing countries could ill afford the early retirement of these facilities in order to adhere to the processes of the Protocol.

Consequently, the Protocol created a special exemption for the developing countries. It provided a 10-year lag in Protocol implementation for countries whose per capita consumption is less than 0.3 kg per year. These countries, called Article 5 countries (after the article that specifies this exemption), were also promised all practicable help in ensuring access to technology for substitutes.

At this point, the major developing countries that were not party to the Protocol were India and China. Both these countries largely ignored the Montreal Protocol formulation process as they were relatively minor users of CFCs (in the late eighties, they together accounted for about 5% of world consumption; Shea, 1989).

However, both countries soon had to take note of the Protocol. There were two reasons for this. The first was that the Protocol imposed strong restrictions on the import and export of CFCs and of products using CFCs. The trade of these compounds with non-Parties was banned within a year of the Protocol's entry into force. The Protocol also contained a provision for the consideration of banning trade of CFC-containing products with non-Party countries. This occurred at a time when the exports of both CFCs and of refrigerators from India were just picking up. The Protocol seemed to be a closing gate to the India CFC and refrigerator exporters.

The second reason was that both India and China became the focus of attention for the international community. The large size of these countries, their self-sufficiency in CFC-production, and their rapid growth rates indicated a potential for the skyrocketing of global CFC use. It was felt that, "if India and China achieve their modernization and electrification goals for the next decade, all CFC abatement efforts by the industrialized countries would be nullified" (Rosencranz and Milligan, 1990).

In the perspective of the international pressure, and the growing scientific evidence of the increases in ozone destruction, the Government of India took cognizance of the issue in 1988. At a meeting in the Ministry of Environment in that year (at which this author was present), the scientific ministries urged Indian ratification of the Protocol. The Ministry of Industry (which had just prepared its assessment; Government of India, 1988) pointed out that CFC/halon substitutes would be four to five times as expensive as the ozone-depleting substances that they would replace. The argument was ultimately tilted in favour of the costs-proponents through the issue of domestic refrigerators. The refrigerator, which was shedding its image as a luxury good, was now penetrating new markets amongst the lower middle-class and the rural population. The second-hand market was also thriving, and personal anecdotes of 20-year life of refrigerators (with one or two recharges) abounded. The Government decided that it could not penalize refrigerator owners (for many of whom this purchase was the largest single investment ever made by them) by denying the CFC-recharge and thus forcing them to buy a new (non-CFC) refrigerator.

Later that year, at the UNEP Ministerial Meeting on the Montreal Protocol in Helsinki, the Minister for Environment stated, "The developing countries muster the resources necessary to meet the minimum needs of their citizens at great sacrifice. These countries will be unable to spare further resources for the substitutes to CFCs. The poor of the developing countries will look askance at a government that spends resources on substitutes to CFCs to prevent depletion of the ozone layer.....while they continue to wallow in poverty, hunger, disease and ignorance.

The Government as an observer to the Bureau of Parties to the Montreal Protocol, initiated an amendment to the Protocol that would provide for international funding to meet the costs of implementing the Protocol in the Article 5 countries. The Government also agreed to a British offer of carrying out a study to assess the costs of Protocol implementation in India. By 1990, Mrs. Maneka Gandhi, who had become Environment Minister, urged halting of domestic production of CFCs, and demanded that substitute technology be made available at no, or low cost.

She also insisted that foreign companies provide free CFC-alternative patent rights to the developing countries that need them.

The first reaction of the industrialized countries was to view the demand for international funding as blackmail (see, for example, Moritz, 1989). The developing countries, led by India and China, took the high moral ground and invoked the, "polluter pays principle"; pointing out that since the vast majority of CFC emissions had occurred from the industrialized countries, the costs incurred by the developing countries in phasing out their use should be borne by the former. This point of view was quickly accepted in principle by most industrialized countries, but commitment to provide the funds for meeting the costs related to the Protocol implementation were less forthcoming.

In 1990, new scientific assessments relating CFC emissions to projected ozone depletion were published. These indicated that severe depletion of the ozone layer could be expected even if the CFC consumption limits laid down in Protocol were observed (see, for example, Bruhl and Crutzen, 1990). These studies reinforced the need for adjustments for the CFC consumption limitations so as to minimize ozone depletion. It also highlighted the need to ensure that major developing countries like India and China joined the Protocol.

In the perspective of the scientific findings, and the strong stand taken by India and China, the Parties to the Protocol agreed to amendments that would allow the developing countries to be compensated for costs associated with Protocol implementation. An ad-hoc financial mechanism called the Interim Multilateral Fund, was established at the June, 1990 meeting in London with a core funding of US$ 160 million to go up to US$ 240 million and US$ 320 million as China and India joined the Protocol. The Fund was to be financed by payments from the industrialized countries; each country's contribution calculated in accordance with its UN assessments.

At the London meeting, the CFC phaseout limits were also considerably tightened in response to the findings of the scientific assessments. The industrialized countries were required to completely phaseout most ozone depleting substances by the year 2000. In addition, Carbontetrachloride and methyl chloride were added to the list of the controlled substances.

After the June 1990 meeting there was again considerable international pressure on India and China to immediately join the Vienna Convention and the Montreal Protocol. In 1991, China signed the Protocol. India steadfastly refused to sign until the London amendments came into force after ratification by an adequate number of Parties. Soon after this occurred, India signed the Vienna Convention in March 1992, and then the Montreal Protocol in June 1992. Following a statutory three-month waiting period, India become a Party to the Montreal Protocol in September 1992. In the 4th meeting of the Parties held in Copenhagen in November 1992, the Indian Minister for Environment and Forests, Mr. Kamal Nath was elected President of the Bureau of the Parties to the Montreal Protocol.

Implementing the Montreal Protocol in India

The ad-hoc financial mechanisms of the Protocol was granted statutory approval at the Copenhagen meeting in November 1992, and Multilateral Fund of the Protocol came into existence from 1st January 1993. The Fund is managed by 14 member Executive Committee established by the Parties, which has a balanced representation of Parties which belong to the industrialized countries and those belonging to Article 5 countries. The Executive Committee meets thrice a year to consider and approve requests for funding submitted to it. The committee is assisted by the Fund Secretariat based in Montreal. Projects and activities are undertaken through four international organizations which are designated as Implementing Agencies. These are UNDP (United Nations Development Programme, the World Bank, UNEP (United Nations Environment Programme), and UNIDO (United Nations Industrial Development Organization). These implementing agencies develop projects in collaboration with the countries, present them for approval to the Fund, and then supervise the project implementation.

The contribution to the Multilateral Fund have been fixed at $ 113 million for 1993. The level of funding for the 3-year period from 1994 to 1996 will be in the range of $ 340 to 500 million; the exact quantum is to be decided at the next meeting of the Parties in November this year.

In order to assess their funding requirements, in the perspective of their national strategy for the implementation of the Montreal Protocol, all Article 5 countries are required to prepare Country Programmes. These Country Programmes look at the current structure of the ODS user and producer sectors, their anticipated growth rates, define the phaseout strategy in the various users sectors, assess and evaluate technical options for phaseout, and assess the cost of phaseout.

After India became a Party to the Montreal Protocol, the process of Country Programme preparation and identification of projects for funding commenced. The Ministry of Environment and Forests chose UNDP as the Implementing Agency for Country Programme preparation. Broadly, it was agreed that World Bank would the Implementing Agency for large investment projects. the UNDP for smaller investment projects. UNIDO for projects in the small scale sector and UNEP for projects related information dissemination and awareness. An Ozone Cell was created within the Ministry of Environment and Forests to be the nodal agency for Montreal Protocol implementation.

In March this year, the Ministry of Environment and Forests and UNDP identified the Tata Energy Research Institute to be the lead agency for the preparation of the Country Programme. Throughout the process of Country Programme formulation, there has been a continued emphasis on close government-industry interaction. There has been a conscious effort to involve industry as an equal partner in formulating the programme so that they have a stake in the implementation of the programme as well. The first government-industry meeting was held in New Delhi in January this year. Following this, there were several workshops related to project preparation for examining the technical options and strategies for phaseout in various users sectors (i.e. Refrigeration and Air

Conditioning, Foams, Aerosols, Solvents and Fire Fighting). Sectoral groups, consisting of industry representatives were formed in June 1993 to draft sectoral recommendations for the Country Programme. They were assisted by international experts provided by UNDP. These drafts were prepared and presented at a national workshop on the Country Programme in July this year. These were then assessed and integrated in the perspective of the national phaseout strategy.

Figures 4 shows the expected growth of ODS use in various sectors till 2010. The Montreal Protocol requires phaseout of various groups of ODS according to specified time tables. The limits imposed by the Montreal Protocol and the phaseout profiles for the four groups of ODS used in India are shown in Figures 5 to 8. In arriving at these phaseout profiles, various technical options were examined. In the Aerosols sector, the strategy is to move from CFC to LPG. In the Refrigeration sector, the preferred strategy is presently seems to be move to a completely fluorinated fluorocarbon (or, Halogenated Fluorocarbon) HFC-134a. In the Foams sector, the strategies are not very clear as yet; there is some move towards hydrocarbons, and new HFCs may be preferred in certain options. In the Solvents sector, the move is largely towards water based systems. In certain pharmaceutical solvents applications, the use of CFCs will continue, and is allowed under the provisions of the Protocol. In the Fire Fighting sector, Halons will have to be completely phased out. There are plans to build up a bank of Halons so as to provide a buffer stock till substitutes become available. In this sector, the Protocol allows retaining some halon use for essential purposes.

A major finding that emerged during the process of Country Programme preparation was about two-thirds of CFC used in India occurred in the small scale and informal sectors. During the process, large units using CFCs, as well as larger small scale industries were identified, and included in the programme. However, based on data on supply patterns provided by the CFC producers, it was apparent that large quantities of CFC use had not been included. These were assumed to occur in small scale and informal sectors. We currently estimate that the unidentified small and tiny units accounts for 26% of ODS consumption in the refrigeration and air conditioning sector; 45% in the Aerosols sector; 40% in the Solvents sector; and 6.7% in the Fire Fighting sector. The unit cost of phaseout in the small and tiny units have, at present been estimated to be 250% of that in the larger (identified) units.

There was also concern about the CFC based refrigerators that would still be in service after 2010, and may need a CFC recharge. It was decided that the Country Programme would approach this problem through three options. It would provide an incentive for trading in these refrigerators; it would establish a CFC recycling programme; and it would help in retrofitting CFC refrigerators so that they could be charged with non-CFC refrigerants.

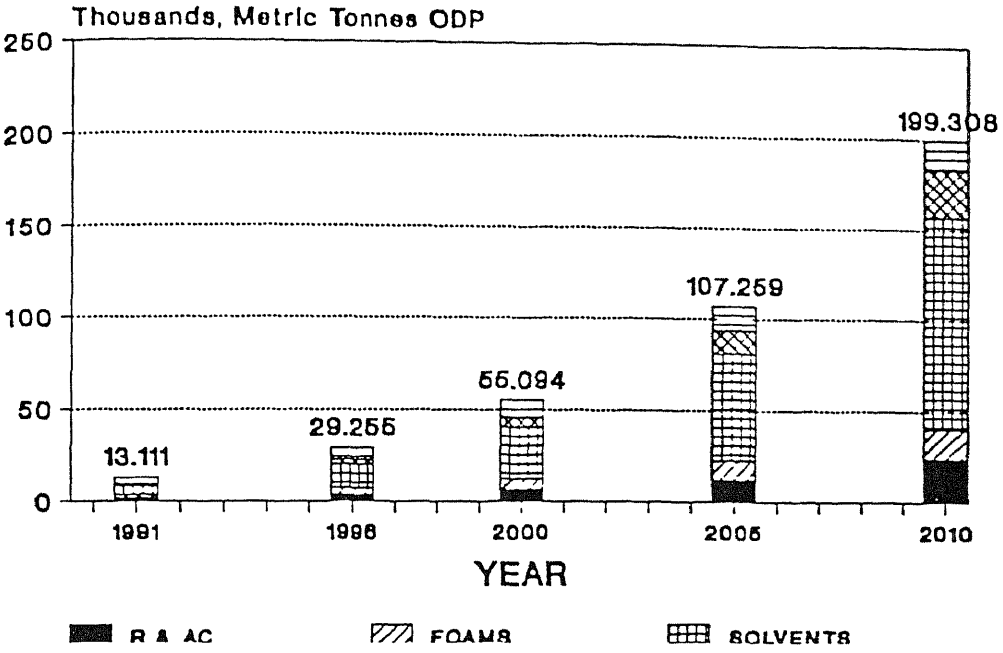
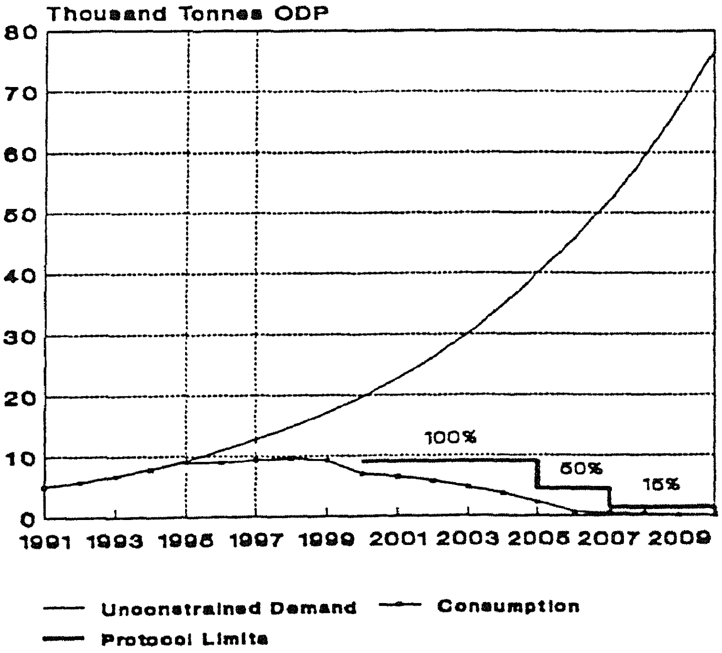
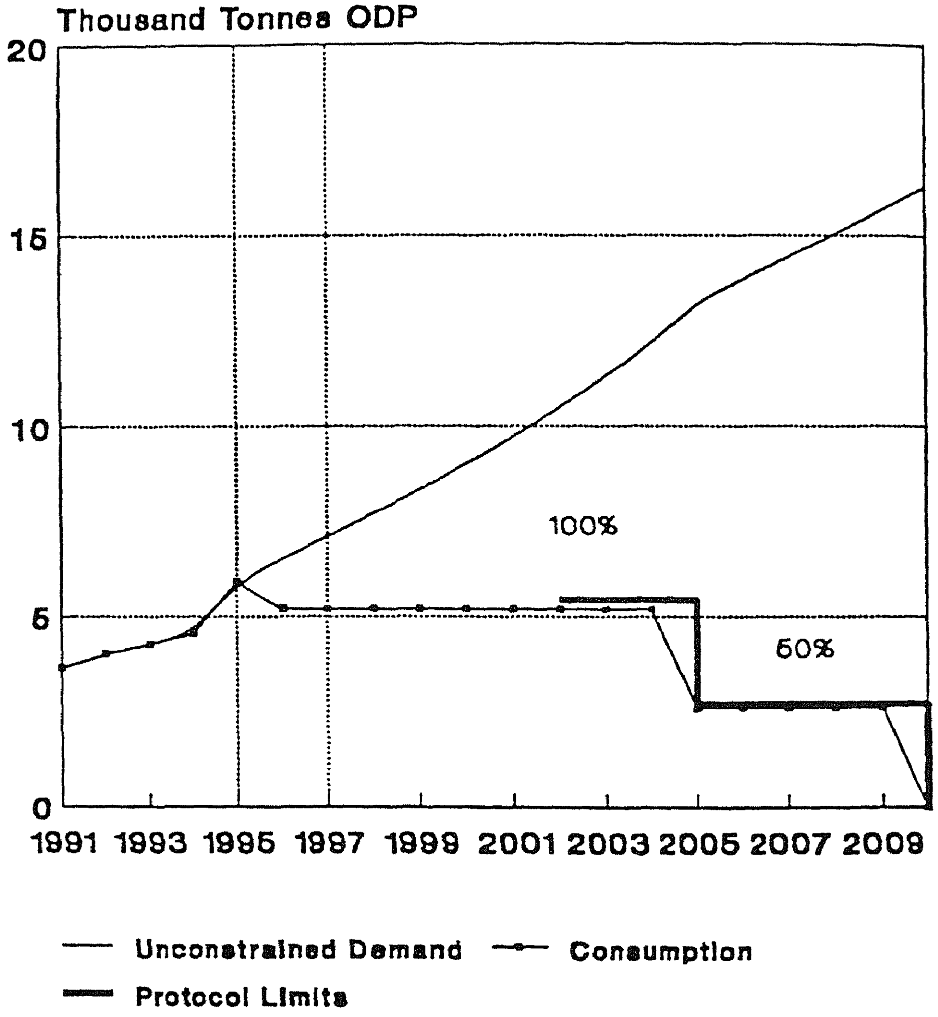


Figure 4: Estimated unconstrained ODP demand by sector to the year 2010.



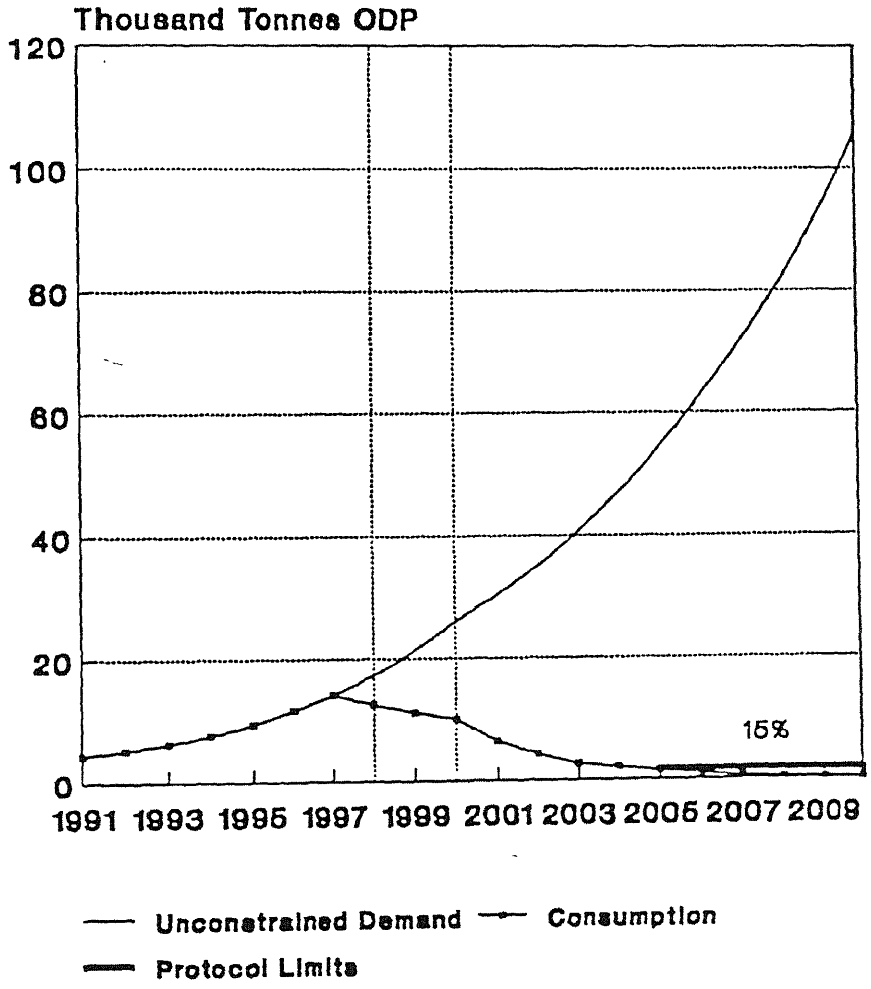
Protocol limit percentages are based on average consumption in the years 1995 to 1997

Figure 5: Phaseout of Annex A Group I ODS (CFC-11, CFC-12 and CFC-113) in India.



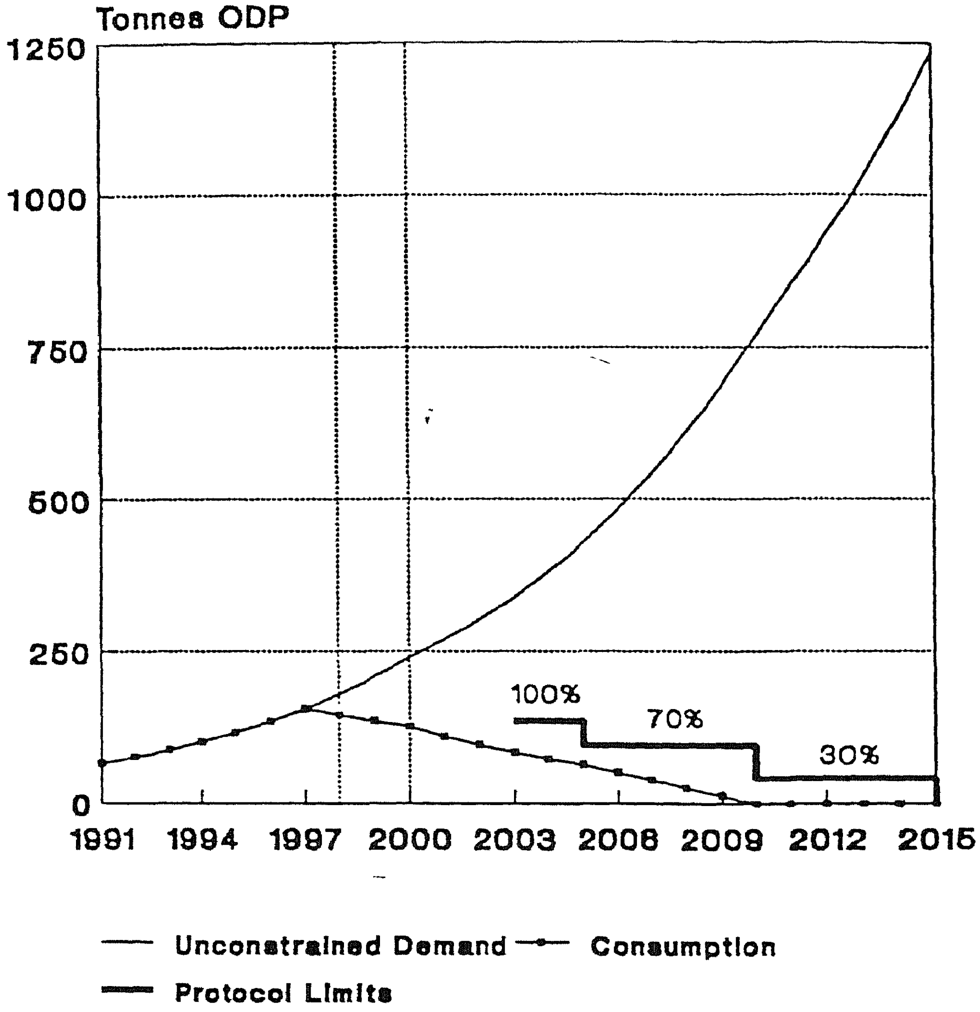
Protocol limit percentages are based on average consumption in the years 1995 to 1997

Figure 6: Phaseout of Annex A Group II ODS (Halon-1211 and Halon-1301) in India.



Protocol limit percentages are based on average consumption in the years 1998 to 2000

Figure 7: Phaseout of Annex B Group II ODS (CTC) in India.



Protocol limit percentages are based on average consumption in the years 1998 to 2000

Figure 8: Phaseout of Annex B Group III ODS (MCF) in India.

The one other major problem faced by India is the issue of the availability of CFC substitutes. India is one of the five Article 5 countries that has indigenous production of CFCs. In fact, over the last 5 years, India has been exporting CFCs to various developing countries. The CFC manufacturers have also installed large plants in view of their rapidly increasing consumption. The Country Programme seeks to compensate the CFC producers for their lost capacity, as well as to help them to establish new facilities for the production of CFC substances in the country.

The integrated Country Programme was presented at the second national workshop in August. It was subsequently approved by an inter-ministerial group, and then by the Union Cabinet on September 5, 1993. The net incremental costs of phaseout are presented in Table 1.

Conclusions

The national and international processes that have occurred as a result of the finding that CFC emissions harm the ozone layer bring out five salient features. These are briefly discussed here.

The role of science in international agreements

The Rowland-Molina hypothesis and its subsequent confirmation sparked off various national initiatives to reduce CFC emissions. Subsequently, scientific evidence indicating increasing ozone depletion over a period of time served to highlight the urgency of the process. Undoubtedly, the threat of increased skin cancer due to enhanced UV radiation served to influence the decisions of many individuals to support the ban on CFCs. The political pressure of such individuals has been large enough in a large number of countries so as to enable the formulation of the Montreal Protocol.

The Protocol has also explicitly recognized the inputs provided by scientific observations, and the need to adjust international actions (for CFC limitation) so as to take new scientific data into account. As a result, adjustments are possible, and have been used to accelerate the CFC phaseout process in response to new scientific evidence. As a result of the last such assessment, the phaseout schedule in the industrialized countries has been advanced from the year 2000 (as agreed at London meeting) to the year 1996. However, at Copenhagen, the phaseout limit for the developing countries was not concurrently forwarded to 2006 (in the perspective of the ten year lag), but provisionally maintained at 2010. A decision whether the developing country phaseout limit should be brought forward to 2006 would be taken after the next assessment becomes available in 1995.

The Country Programme will now be transmitted to the Multilateral Fund for consideration at the next meeting of the Executive Committee to be held in November this year.

Table 1: Net incremental cost of ODS phaseout

Sector	Incremental costs ($ million)	ODP phaseout tonnes	Unit phaseout (US $/kg)
Aerosols	13	14366	0.90
Foams	150	14866	10.08
Fire Fighting	36	15208	2.37
Domestic refrigeration	295	5000	59.00
Other refrigeration and AC	120	11884	10.10
Solvents	104	69944	1.49
Trade-in of refrigerators and other appliances	325	200	1625
Recovery and recycling	50	2500	20
Chemical producers	466	-	-
Small scale and informal sector			
Other R&AC	105	4176	25.25
Foams (non-refrigerator)	84	1669	50.43
Aerosols (fillers only)	21	11754	1.75
Solvents	174	46629	3.73
Fire-fighting	6	1092	5.93
Sub total	390	65320	5.97
Administrative cost	15	-	-
Total	**1964**	**199308**	**9.85**

Note: 1. The above net incremental costs have been arrived at by computing the eligible costs on an annual basis upto the year 2010, at the 1993 value of US $.

The polluter-pays principle

The special consideration for developing countries that is built into the Protocol highlights the differentiated responsibility of the industrialized and developing countries in contributing to the ozone depletion problem. Though the Protocol states that the provision for the transfer of financial resources should not be considered as an international precedent, the weight of international public and moral opinion clearly recognizes this differentiated responsibility. It has now also been built into the Climate Change Convention.

It has also resulted in the concept of incremental costs in developing countries due to changes required because of international obligations. The evaluation of incremental costs, and the modalities for meeting these incremental costs are being presently established. The Multilateral Fund currently operates with a few, generic rules, and decides on issues on a case-by-case basis. During this process, the eligibility of various costs for being considered as incremental costs is tested, and international precedents established.

Government-industry interactions

For the first time in India, government and industry have worked to produce a common national document. For this reason, many have preferred to call a Country Programme as a national programme. It highlights the great potential for achieving clear goals in a timely manner when both the government and industry agree to undertake specific responsibilities. A major feature of the process is that it also engendered a close working relationship between companies that are fierce competitors in the market. The interactions revealed that industry is willing to make adjustments so as to realize national environmental goals.

Technology transfer

The Multilateral Fund process has spawned a new form of technology transfer. Individual companies in the industrialized and in the developing countries agree to technology transfer under the provisions of the Protocol. In the process of national and international project approval, the technology transfer arrangement is vetted for technological suitability as well as for economic efficiency. Consequently, it promotes the transfer of state-of-the-art technologies at internationally competitive prices. This is quite at variance with what was expected when the process started. It was felt at that time companies in the industrialized countries would charge large royalties for technology transfers.

This process has also forced a much closer interaction between industrial units across the world, and given rise to innovative forms of technology development.

For example a US inventor is using an Indian company to develop the engineering plans and prototypes for a new (non-CFC) car air-conditioner for the US market. Similarly, several European aerosol manufacturers are considering building filling plants in India. Leading-edge technology companies in areas such as refrigerator compressors are developing joint venture relationships with Indian companies.

Changing life styles

The Montreal Protocol process has demonstrated that people worldwide are willing to change lifestyles and incur personal costs so as to enhance environmental quality. This preference is also exhibited at the national level where the industrialized countries are willing to spend public money on amelioration of international environmental problems. For example the United States, which has been a chronic defaulter in paying its dues to UN organizations, is the only country to have met and exceeded its assessed dues to the Multilateral Fund.

The Protocol process has, above all, demonstrated the capability to, and the willingness of, countries to seriously negotiate potentially major economic transformations so as to achieve global environmental quality. It has, therefore, redefined the existing vested interests in international power-diplomacy, and opened the way for a new set of international bargaining aimed at environmental protection and sustainable development.

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Clean Vehicles versus Congestion: Will Metropolises in India Stabilize Emissions?

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Clean vehicles versus congestion: will metropolises in India stabilize emissions?

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Abstract

Four metropolises in India - *Delhi, Calcutta, Bombay and Bangalore* - are selected for a comparative analysis to illustrate the effect on automotive emissions of two much discussed strategies for mitigating adverse impacts of road based passenger transportation system. The strategies considered here are: (1) reducing urban congestion by strengthening public transport system and (2) promoting efficient engines by phasing out two-stroke technologies. The paper analyses the nature and magnitude of the energy use and emissions in each of the four cities under the business-as-usual (BAU) scenario 1 and the two strategies mentioned above. Driving forces considered for analysing energy demand are:- growth in registration of different vehicles, average utilization, occupancy and fuel consumption pattern of different modes and penetration of different technologies. The resultant mass emissions of five criteria pollutants viz., CO, HC, NO_x, SPM and SO_2 are estimated by multiplying energy consumption by different modes – further broken down into technologies – and their corresponding emission factors. Results of scenario 2 and 3 are compared separately with the BAU scenario, to determine the likelihood addition/reduction in energy demand and emissions by alternative modes in 2000-01. The paper reveals that in scenario 2, with a 20% shift towards public bus from the usage of personalized modes (like, two-wheelers and cars) in 2000-01, while meeting the same level of total passenger travel as estimated in BAU case, total energy demand is expected to decline to about 15% each in Delhi and Calcutta, 17% in Bangalore and 22% in Bombay. Also, introduction of more buses would reduce congestion on city roads considerably. About 47% of the total vehicles in Bangalore, 41% in Bombay, 39% in Calcutta and 22% in Delhi is likely to be off the road during 2000-01 as compared to the BAU scenario results. Similarly, the reduction in emissions is very significant in the case of CO (as high as 54% in Bombay and as low as 35% in Delhi), HC (73% in Bombay to 45% in Delhi), SPM (7.5% in Calcutta to 18.2% in Bombay). But emissions of NO_x and SO_2 (except in Bombay) is likely to increase marginally in scenario 2. In fact, strengthening of public transportation in each city is expected to either stabilize or even reduce emissions of CO, HC and SPM with respect to their present loading levels. In scenario 3, with 45% phasing out of two-stroke engines (i.e., scooters & motorcycles) and replaced by four-strokes in 2000-01, would also reduce energy demand and emissions, but marginally, when compared with the BAU scenario results. In other words, the extent of reduction in energy demand and emissions is comparatively insignificant in scenario 3 as against scenario 2 when they are compared separately with the BAU case. Given the growing large polluting fleet, the technological fix alone is not sufficient to combat energy demand and air pollution problems in Indian cities. Demand management measures are necessary to complement supply side nterventions in controlling the main pollutants from motor vehicles.

Introduction

In India, with the technology import liberalization policy of the government, and the establishment of several international collaborations, the automobile policy in 1985 allowed the manufacturers to produce any type of vehicle, from passenger cars to heavy commercial vehicles. There was no constraint on engine size or any attempt at obtaining an appropriate mix of vehicles from the view point of fuel efficiency, pollution, axle load, chassis configuration and with a view to minimize transportation costs.

The rapid increase in two-wheeler and private-car population is making unrestricted claims on valuable road space and energy resources, particularly in urban areas. While on the one hand, the vehicle mix in urban areas has aggravated congestion and air pollution, on the other, specifically production of buses and their design for urban mass transportation has not received adequate attention in the national automobile policy. Air pollution problems are mainly contributed by automobiles[1] and are confined to the large size cities. Over two-third of the total registered fleet in large size cities comprise of two-wheelers of which over 90% run on two-stroke engines, while the remaining are four-stroke.[2] The advantages of 4-stroke engines in terms of energy consumption and emissions are enormous. Conversion of two-stroke to four-stroke can reduce HC emissions considerably and attain higher fuel economy.

While several studies[3,4,5,6] are available on implications of road based urban transportation on energy demand and emissions in India, but each one of them present a broad understanding of the problem. In most of the studies the range of estimates differ considerably due to the lack of coherent methodologies used. Moreover, given the large number of alternative modes and available technological options, it is of utmost importance to first understand the nature and magnitude of the problem at the most disaggregated level i.e. by technology for each mode, before a corrective measure is implemented.

The paper analyzes the extent to which the two most discussed policies: (1) gradual penetration of new and clean technologies of two-wheelers, and (2) strengthening of public transport system (to reduce urban traffic congestion) are expected to offset the growing demand of energy and emissions by 2000-01 in the four cities – *Delhi, Calcutta, Bombay* and *Bangalore*. Energy demand estimates and resultant emissions of five criteria pollutants viz., CO, HC, NO_x, SPM and SO_2 are estimated for different modes and their respective technologies. Results are obtained under three scenarios. Scenario 1 -- the "business-as-usual" (BAU) -- assumes that different type of vehicles in each city will continue to grow as per their present trends without any policy interventions in during the five year period (1995 - 2000). Scenario 2 assumes strengthening of public transport system to reduce urban congestion, while scenario 3 assumes phasing out of two-stroke technologies and replaced with four-strokes, to promote clean and efficient engines. Results of scenario 2 and 3 are compared separately with the BAU case to estimate the likelihood reduction/addition in energy demand and emissions.

Framework for analysis

The following equations are used for estimating growth of vehicles, travel demand, energy requirement and emissions for the base year 1995-96 and the reference year 2000-01 in each of the four cities.

Number of vehicles which were registered after 1973-74 are regressed with time in each of the four cities to extrapolate their growth. The functional form of the linear regression is given in Eq.(1).

$$V_{tk} = a + b\,t_k \qquad k = 1,2,.....,6 \tag{1}$$

where, V_{tk} denotes the number of registered vehicles (after 1973-74) of type (or mode) k in time period t [t= (n+1) - 1984-85, with n = reference year]. The coefficients in Eq.(1) is obtained by the ordinary least square method. Index k in Eq.(1) denotes mode of transport. Data on registration of vehicles are available for six modes. These include two-wheeler (scooter, motor-bike and moped), three-wheeler autorickshaw, car and jeep, taxi, bus and the goods vehicle. The distribution of five passenger modes are further disaggregated into types of technologies using the national production distribution data. For instance, among two-wheelers four type of technologies are considered viz., scooters, motor-bikes, mopeds which runs on two-stroke engines and the four-stroke motor-bikes. Similarly, for car, jeep and taxis together, four types of technology are considered. These are gasoline based pre-1984 and post-1984 models, the post-1994 model with catalytic convertors, and diesel vehicles. However, only one technology is considered for three-wheeler and bus.

Travel demand catered by different modes and technology in year t is given by Eq.(2).[7]

$$PKM_{it} = V_{it} \times U_i \times O_i \qquad i = 1,2,.....,10 \tag{2}$$

where, PKM denotes passenger travel demand expressed in passenger kilometre (pkm), V denotes the number of motorized vehicles obtained in Eq.(1), U denotes average vehicle utilization and O denotes the average occupancy of vehicle. The index i denotes the mode of transport and their respective technologies. Total passenger travel demand is the aggregation of travel demand across different modes.

Energy demand by various modes and technologies in year t is estimated by using Eq.(3).

$$FD_{it} = PKM_{it} \times E_i \qquad i = 1,2,.....,10 \tag{3}$$

where, FD denotes annual fuel demand depending upon the mode and technology considered, which is expressed in litres (l). E denotes the operating energy intensity[a] of each mode and technology, expressed in litres per pkm (l/pkm).[8] Total energy demand is obtained by converting fuel demand by each mode into a common energy unit say, kgoe[b] and then aggregated together.

Annual emissions of five criteria pollutants CO, HC, NO_x, SPM and SO_2 by different modes and technologies of transport are estimated by using Eq.(3).

$$P_{ijt} = FD_{it} \times EF_{ijt} \qquad i = 1,2,.....,10 \text{ and } j = 1,2,.....,5 \tag{4}$$

where, P denotes emissions expressed in tonnes and EF denotes emission factors expressed in grams per litre of fuel burnt (g/l). Index j denotes the type of pollutant considered. Total annual emissions of a pollutant can be obtained by aggregating the emission values across different modes and technology.

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[a] The operating energy intensity represents the fuel efficiency of different modes of vehicles. It measures the amount of energy needed to move 1 person over 1 km by a given mode.

[b] 1 kl of gasoline = 0.7499 kilogram of oil equivalent (kgoe) and 1 kl of diesel = 0.8552 kgoe.

Scenario construction and assumptions

Three scenarios are considered to study the impact of different urban transport policy initiatives that would reduce total energy requirement and emissions in the road based passenger transportation in the four cities - *Delhi, Calcutta, Bombay* and *Bangalore*. These scenarios are defined below:

Scenario 1: Business-as-usual

This scenario assumes that the present trends of growth in registration of vehicles in each of the four cities will continue, while the present fuel efficiency norms, occupancy level and vehicle utilization pattern for different modes will remain unchanged until 2000-01.

Scenario 2: Increasing the share of buses

It is assumed that, with incentives for greater investment in and use of bus, in each city a 20% shift in the estimated total passenger travel demand in 2000-01 will be towards use of bus with a corresponding decline in usage of personal vehicles like two wheelers (viz., scooters, motor-cycles and mopeds) and passenger cars and jeeps. With greater use of buses in scenario 2, congestion of traffic will decline and the overall efficiency of passenger movement will increase. More specifically, (1) total passenger travel demand in each city during 2000-01 would remain at the same level as obtained in the BAU scenario, (2) modal split -- distribution of travel demand catered by different modes -- for bus during 2000-01 in each city would increase by 20%. With this, the modal split for bus in Delhi would increase from about 61% in BAU to 73% in scenario 2. The corresponding increase in Calcutta would be from 67% to 80%, while in Bombay and Bangalore from 71% to 85%, and (3) contribution of travel demand by two-wheelers, three-wheelers and cars, jeeps and taxis together would decline in Delhi by 25%:45%:30%, Calcutta 25%:40%:35%, Bombay 25%:42%:33% and Bangalore 49%:25%:25% respectively.

Scenario 3: Phasing out of two-stroke engines

This scenario assumes that by 2000-01, in each city 45% of the total two-wheeler fleet (only scooters) which otherwise would have run on two-stroke engines will be phased out, and would be replaced with four-stroke engines. In other words, scenario 3 envisages introduction of clean technologies in a phased manner to attain higher efficiency of energy utilization and consequent reduction in emissions for certain pollutants.

Results and analysis under BAU scenario

Growth of motor vehicles

Table 1 gives the growth in total number of registered vehicles, their composition and annual growth rates for each of the four cities. Eq.(1) is used to estimate the growth of vehicles in each city. Delhi has the largest number of registered motorized vehicle in the country (2.34 million in 1995-96) which is

Table 1. Growth of registered vehicles, its composition and projections in the BAU scenario

City	Financial year (March-April)	Total vehicles registered (million)	Changes in vehicle composition (%)						Annual growth rate over the last five years (%)						
			2-wh	3-wh	car & jeep	taxi	bus	goods	2-wh	3-wh	car & jeep	taxi	bus	goods	all
Delhi	1990-91	1.59	72.18	3.50	18.14	0.47	0.81	4.90	14.8	16.9	23.3	9.0	11.6	15.4	16.2
	1995-96	2.34	71.01	3.39	19.49	0.44	0.84	4.82	7.7	7.4	9.6	6.6	8.9	7.7	8.0
	2000-01	3.14	70.03	3.36	20.59	0.42	0.83	4.77	5.7	5.8	7.2	4.8	5.6	5.8	6.0
Calcutta	1990-91	0.39	46.58	4.55	35.00	3.61	2.28	7.98	12.9	41.8	10.8	13.3	26.6	7.7	12.5
	1995-96	0.55	47.93	5.25	33.53	3.61	2.26	7.42	7.5	10.0	5.9	6.8	6.7	5.3	6 9
	2000-01	0.71	48.39	5.83	32.92	3.65	2.30	6.91	5.5	7.6	4.9	5.6	5.7	3.8	5.3
Bombay	1990-91	0.52	43.80	6.68	37.71	4.89	1.05	5.88	10.5	2.0	11.1	5.6	9.6	7.3	9.6
	1995-96	0.71	44.55	5.31	38.99	4.54	1.01	5.59	6.9	1.8	7.3	5.0	5.9	5.5	6.6
	2000-01	0.90	44.92	4.56	39.75	4.31	1.01	5.46	5.0	1.7	5.2	3.7	4.7	4.3	4.8
Bangalore	1990-91	0.52	80.26	3.15	12.08	0.34	0.90	3.27	17.4	14.4	13.9	12.6	11.3	12.9	16.6
	1995-96	0.76	79.44	3.81	11.66	0.30	0.81	3.99	7.7	12.1	7.1	5.2	5.5	12.3	7.9
	2000-01	1.01	79.56	3.85	11.46	0.29	0.75	4.10	6 0	6.2	5.6	4.8	4.6	6.5	6.0

Note: Data on vehicles registered for the period 1984-85 to 1993-94 (excluding pre 1973-74 vehicles) are considered for the time trend Eq.(1) using reference no. 9.

Table 2. Passenger travel demand and its distribution by different modes and their technologies in the BAU scenario

City	Financial year (March - April)	Distribution of travel demand catered by different types of technologies (%)										Total travel demand (bpkm)
		2-wheelers (gasoline)				3-wheeler (gasoline)	Car, jeep & taxi (gasoline)			Car, jeep & taxi (diesel)	Bus (diesel)	
		2-stroke			4-stroke		Pre-1984	Post-1984	Catalytic convertor			
		scooter	m-cycle	moped	m-cycle							
Delhi	1995-96	12.13	1.82	0.46	0.76	7.55	0.78	12.95	0.31	1.56	61.67	81.07
	2000-01	12.04	1.05	0.45	1.51	7.53	0.83	5.78	7.44	2.48	60.89	108.00
Calcutta	1995-96	2.75	2.75	0.40	0.81	6.39	2.02	11.95	0.40	5.87	66.65	28.94
	2000-01	2.54	2.80	0.40	0.93	6.99	1.57	3.34	8.85	5.90	66.68	38.13
Bombay	1995-96	2.18	2.77	0.66	0.99	6.84	3.30	7.93	0.33	4.96	70.04	35.67
	2000-01	2.02	2.96	0.54	1.21	5.94	3.01	1.17	7.53	5.02	70.58	44.58
Bangalore	1995-96	4.90	2.52	4.34	2.24	5.83	0.39	5.03	-	2.32	72.44	31.82
	2000-01	4.85	2.06	5.00	2.79	6.18	0.32	4.86	-	2.79	71.16	40.54

more than the total number of vehicles in Calcutta, Bombay and Bangalore taken together (2.02 million). The average annual growth rate of each mode has declined considerably after 1990-91 as compared to the period between 1985 and 1990. Currently, Delhi and Bangalore is experiencing a higher annual growth rate (around 8%) of all vehicles together as compared to Calcutta and Bombay where the corresponding figure is nearly 7%. In terms of vehicular composition in 1995-96, share of bus with respect to the total registration of fleet is between 1 and 2% in the four cities, while the corresponding share of personal modes (two-wheelers, car and jeep) is between 80 and 90%. Delhi and Bangalore has relatively a higher share of two-wheelers (71% and 80% respectively) as compared to cars and jeeps (19% and 12% respectively), while in Bombay and Bangalore the corresponding share is 48% and 45% respectively for two-wheelers, and 34% and 39% respectively for cars and jeeps. Share of three-wheeler and taxi is relatively higher (around 5% and 4% respectively) in Bombay and Calcutta as compared to Delhi and Bangalore (3.5% and 0.4% respectively). Nearly one-third of the total vehicles registered in 1995-96 in each city is likely to be added to the fleet stock by 2000-01, without much of a deviation in the existing vehicular composition (Table 1).

Passenger travel demand and modal split

Table 2 gives the estimated travel demand and its distribution by various modes and their respective technologies for 1995-96 and 2000-01. Secondary data on average occupancy and vehicle utilization of different modes are used for Eq.(2).[9,10] Travel demand in Delhi is expected to grow at the rate of 7.4% annually between the period 1995-96 and 2000-01 (from 81 billion passenger kilometre (bpkm) to 108 bpkm). The corresponding figures for the other cities are: Calcutta 7.1% (from 29 to 38 bpkm), Bombay 5.7% (36 to 45 bpkm) and Bangalore 6.2% (from 32 to 41 bpkm). In spite of a very large fleet stock of personalized modes (two-wheelers, cars and jeeps) in each city, bus caters to a very high volume of travel demand and is expected to remain around the same level in the coming years. In Delhi, currently, bus meets nearly 62% of the travel demand which is expected to decline marginally in 2000-01. Travel demand being met by bus in Calcutta and Bombay is around 67% and 70% respectively, which are likely to increase marginally during 2000-01. In Bangalore, almost 72% of the travel demand is catered by bus in 1995-96 which is expected to decline, though marginally.

With regards to travel demand catered by different technologies under car, jeep and taxi together, there is likely to be a greater shift in ownership and usage of clean technologies like car with catalytic convertors which are meant for unleaded gasoline. Shift from gasoline engine to diesel engine cars, jeeps and taxis is expected in the near future due to more than double price differential between retail price of gasoline (about Rs 22 per litre) and diesel (about Rs 9 per litre). In the case of two-wheelers, the travel demand to be catered by two-stroke engines (which are highly fuel inefficient due to incomplete combustion) will continue to be higher than that of four-strokes. The three-wheeler autorickshaws is expected to meet between 6 and 8% of the travel demand in the four cities.

Energy demand

Using Eq.(3), total energy demand and its contribution by various modes and technologies is estimated for 1995-96 and 2000-01 in each city (Table 3). Average fuel efficiency norms used in Eq.(3) is given in table 4. The estimated demand of gasoline in Delhi in the first half of 1990 is found out to be around 16-20% higher compared to the available data on gasoline sales.[11] Similar result is also observed by

Table 3. Energy demand and breakup of demand structure across different technologies and modes in the BAU scenario

City	Financial year (March-April)	Total energy demand (thousand toe)			Share of demand by various technologies and mode (%)									
					Gasoline								Diesel	
		Gas.	Diesel	Total	2-wheelers				3-wh	Car, jeep & taxi			Car, jeep & taxi	Bus
					2-stroke			4-st.	2-st.	Pre-1984	Post-1984	Post-1994 catalytic conv.		
					scooter	m-cycle	moped	m-cy.	auto					
Delhi	1995-96	475	364	840	10.82	1.58	0.36	0.50	14.53	2.01	26.24	0.57	4.38	39.02
	2000-01	614	509	1123	10.70	0.91	0.36	1.00	14.43	2.12	11.66	13.53	6.92	38.38
Calcutta	1995-96	147	191	338	2.18	2.11	0.28	0.48	10.91	4.78	22.17	0.68	15.09	41.31
	2000-01	186	252	437	2.04	2.19	0.29	0.56	12.15	3.79	6.32	15.11	15.46	42.09
Bombay	1995-96	228	246	473	1.52	1.87	0.41	0.51	10.28	11.33	21.37	0.80	18.50	33.41
	2000-01	267	310	577	1.44	2.05	0.34	0 65	9.15	10.60	3.24	18.79	19.22	34.52
Bangalore	1995-96	112	164	276	5.22	2.60	4.11	1.78	13.39	1.19	12.19	-	7.80	51.72
	2000-01	145	212	356	5.10	2.10	4.67	2.19	14.00	0.97	11.61	-	9.23	50.13

Table 4. Emission factors and fuel consumption of different modes by type of technology under a typical urban driving cycle in India

Type of technology and mode	Average emission factors across different technologies (g/km)					Fuel cons. (km/l)	Type of technology and mode	Average emission factors across different technologies (g/km)					Fuel cons. (km/l)
	CO	HC	NO_x	SPM	SO_2			CO	HC	NO_x	SPM	SO_2	
Pre-1984 car[a]	28.9 (4.6)	6.2 (5.6)	2.3 (52.9)	0.33 -	0.12 -	10.5 (4.8)	2-stroke scooter[a]	3.38 (61.37)	3.06 (14.49)	0.05 (82.56)	0.15 -	0.02 -	54.11 (12.56)
Post-1984 car[a]	9.5 (18.3)	1.5 (14.1)	1.9 (35.1)	0.25 -	0.08 -	13.36 (13.5)	4-stroke motorcycle[a]	1.9 -	0.72 -	0.39 -	0.08 -	0.03 -	72.6 -
Post-1994 car[b] (catalytic conv.)	2.6 (33.7)	0.3 -	0.6 -	0.08 -	0.06 -	14.8 (9.3)	2-stroke moped[a]	4.5 (36.6)	3.2 (24.0)	0.07 (53.4)	0.08 -	0.02 -	60.81 (12.4)
Diesel car[c]	1.1 -	0.28 -	0.99 -	2.0 -	0.39 -	11.0 -	3-wheeler auto[a]	9.0 (58.3)	7.5 (14.8)	0.26 (21.1)	0.3 -	0.02 -	21.38 (14.7)
2-stroke motor-cycle[a]	2.48 (40.13)	3.18 (19.57)	0.053 (111.31)	0.15 -	0.02 -	55.762 (8.91)	Diesel heavy duty vehicle[c]	12.7 -	2.1 -	21.0 -	3.0 -	1.5 -	3.5 -

Source. [a]IIP. 1994. Vehicle emissions and control perspectives in India - a state of the art report. Engines Laboratory, Indian Institute of Petroleum, Dehradun. [b]Rao I V (personal communications on June 24, 1996), Engineering Division, Research and Development, Maruti Udyog Limited, Gurgaon. [c]Biswas D. 1994. Vehicular pollution: combating the smog and noise in cities. In *Hindu - Survey of the Environment*, p.43.

Note. Figure in parentheses are estimated coefficient of dispersions, expressed in percentage.

the author in an other transportation energy-environment study in Delhi.[12] Higher estimates of gasoline demand in Delhi could be due to the use of normative values of fuel efficiency, occupancy and vehicle utilization levels, each of which would vary under typical driving conditions. The other possible reason could be the vehicles going outside Delhi in most of the cases are expected to meet their fuel requirement from the neighbouring regions.

Total energy demand for passenger transportation in Delhi is highest relative to the other cities. Total energy demand in Delhi is expected to grow at an annual rate of 7.5% between 1985-86 and 2000-01 (from 0.84 million tonnes of oil equivalent (mtoe) to 1.12 mtoe). The corresponding growth rates of energy demand in Calcutta is 6.6% (from 0.34 to 0.44 mtoe), Bombay 5.1% (from 0.47 to 0.58 mtoe) and Bangalore 6.6% (from 0.28 mtoe to 0.36 mtoe) respectively. The share of gasoline demand out of total energy is expected to decline from 57% in 1995-96 to 55% in 2000-01. However, in the other three cities the share of gasoline demand would continue to remain less than half. In fact, in Calcutta the gasoline share would decrease marginally from 43% in 1995-96 to 42% in 2000-01. The corresponding figures for Bombay is 48 to 46% and Bangalore around same level 40% in both the periods. As can be noticed from tables 2 and 3, bus in Delhi consumed nearly 39% of the total energy and contributed over 60% of the travel demand in 1995-96. Similarly, the share of energy demand by bus with respect to the contribution of travel demand are in the ratio of 41%:67% in Calcutta, 33%:70% in Bombay and 52%:72% in Bangalore respectively. These ratios are likely to change marginally in 2000-01 in BAU scenario.

Share in consumption of total energy demand for other modes are also given in table 3. The introduction of new cars with catalytic convertor in 1995 (which can run only with unleaded gasoline) only in the four metropolitan cities viz., Delhi, Calcutta, Bombay and Madras to reduce lead emissions, would result in a high growth in demand of unleaded gasoline over the next couple of years in these cities (table 4).

Emissions

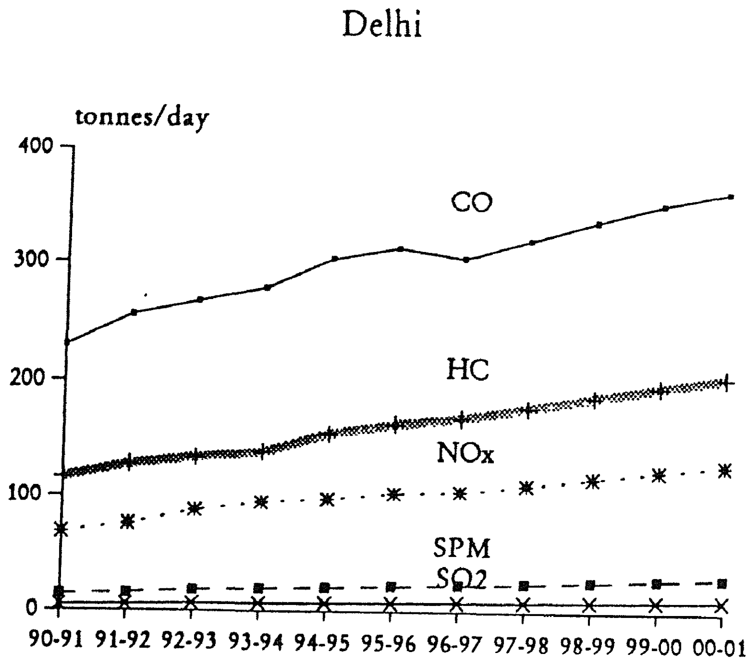
Emission factors of the five criteria pollutants viz., CO, HC, NO_x, SPM and SO_2, with respect to the different range of technologies considered in our analysis have been compiled and presented in table 4. Using these values in Eq.(4), emissions from different modes and technologies are estimated for each pollutant in the BAU scenario. Table 5 gives estimated daily emissions of these pollutants in the four cities during this decade. The table also gives an understanding of the contribution of air pollution by different modes and technologies. Delhi has the highest level of emissions of each pollutant as compared to the other three cities. Figure 1 depicts the trend in emissions of each pollutant in the four cities.

Carbon monoxide

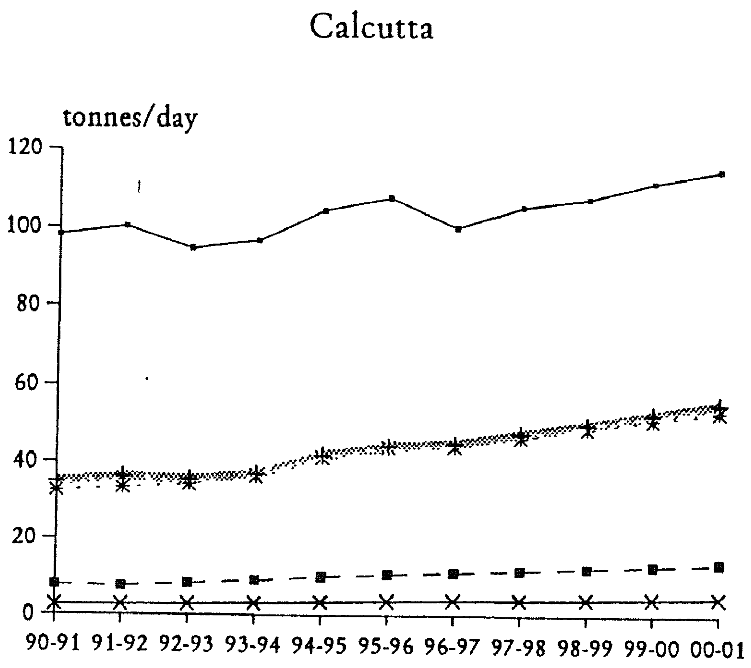
With higher combustion efficiencies in diesel engines as compared to gasoline, CO emission rates is higher in gasoline vehicles. In 1995-96, daily emissions of CO in Delhi was 314 tonnes (t), while for Calcutta the corresponding figure was 108 t, Bombay (175 t), Bangalore (90 t). CO emissions is expected to increase in 2000-01 in Delhi (364 t), Calcutta (115 t) and Bangalore (116 t). However, in Bombay CO emissions is expected to decline marginally from the present level of 175 t to 172 t in 2000-01. Car, jeep and taxi run on gasoline contributes majority of CO emissions in Delhi (39%), Calcutta 51% and Bombay 63%. Bus contributes 13%, 15% and 18% emissions in Bombay, Delhi and Calcutta

Table 5. Total emissions and its contribution by various modes

City	Year	Total daily emis sions (t/d)	Share of loading by different modes (%)					Total daily emis sions (t/d)	Share of loading by different modes (%)					Total daily emis sions (t/d)	Share of loading by different modes (%)				
			Motor gasoline				Diesel		Motor gasoline				Diesel		Motor gasoline or gasoline				Diesel
			2-wheelers		3-wh	Car, jeep & taxi	Bus		2-wheelers		3-wh	Car, jeep & taxi	Bus		2-wheelers		3-wh	Car, jeep & taxi	Bus
			2-st.	4-st.					2-st.	4-st.					2-st.	4-st.			
		Carbon monoxide (CO)						Hydrocarbons (HC)						Nitrogen oxides (NO_x)					
Del	'90-91	230	19.97	0.76	23.17	42.89	13.22	116	38.04	0.58	41.93	15.13	4.32	68	1.33	0.53	2.16	22.47	73.51
	'95-96	314	21.24	0.67	24.20	39.05	14.84	164	39.70	0.50	42 61	12.47	4.72	104	1.27	0.43	2.04	21.87	74.39
	'00-01	364	23.26	1.53	27.79	30.55	16.88	205	39.73	1.05	45.27	8.98	4.96	129	1.30	0.91	2.18	16.73	78.89
Cal	'90-91	98	7.36	0.38	14.57	63.04	14.65	35	19.95	0.41	37.44	35.41	6.79	32	0.42	0.24	1.22	24.93	73 18
	'95-96	108	8.57	0.74	21.34	50.90	18.45	44	21.80	0.70	47.80	22.25	7.46	44	0.41	0.38	1.46	22.83	74.92
	'00-01	115	10.21	1.06	28.74	37.24	22.75	55	22.30	0.85	55.04	13.93	7.86	53	0.43	0.48	1.73	15.92	81.44
Bom	'90-91	168	5.49	0.34	16.47	67 65	10.05	60	14.20	0.37	42.52	38.23	4.68	43	0.40	0.28	1.79	32.36	65.17
	'95-96	175	6.26	0.69	17.32	62.87	12 86	64	17.52	0.73	43.26	32 70	5.80	56	0.38	0.46	1.51	30.70	66.95
	'00-01	172	7.71	1.07	19.13	55.60	16.48	68	20.34	1.05	44.23	27.50	6.88	63	0.41	0.62	1.45	23.13	74.40
Ban	'90-91	72	26.11	1.17	18.14	32.94	21.65	35	44.88	0.92	33 83	13 08	7.29	30	1.12	0.59	1.21	10.81	86.26
	'95-96	90	26.55	2.71	25.71	22.37	22.66	50	42.06	1.89	42.41	6.89	6.75	39	1.10	1.30	1.63	10.35	85.62
	'00-01	116	27.12	3.33	26.78	20.88	21.89	65	41.33	2.29	43.61	6.34	6.43	49	1.14	1.64	1.75	10.44	85.03
		Total suspended particulate matter (SPM)						Sulphur dioxide (SO_2)											
Del	'90-91	14	15.00	0.51	13.84	20.91	49.74	5	5 92	0.57	2.80	17.62	73.09						
	'95-96	23	13.96	0.40	12.62	24.26	48.76	8	5 59	0.44	2.57	19.16	72.24						
	'00-01	30	12.95	0.78	12.43	26.30	47.55	10	5.17	0.86	2.52	21.18	70.25						
Cal	'90-91	8	4.02	0.20	6.79	46.00	42.98	3	1.73	0.23	1.40	32.22	64.43						
	'95-96	11	4.22	0.32	8.01	43.81	43.64	4	1.76	0.36	1.66	30.26	65 96						
	'00-01	14	4.25	0.38	9.09	40.95	45.33	5	1.74	0.42	1.85	28 84	67.15						
Bom	'90-91	10	3.56	0.24	10.24	46.58	39.37	3	1.67	0.28	2.16	35.59	60.30						
	'95-96	15	3.43	0.34	7.52	53.53	35.18	5	1.56	0.41	1.67	39.67	56.69						
	'00-01	18	3.59	0.44	6.88	51.77	37.32	6	1.56	0.51	1.47	38.60	57.86						
Ban	'90-91	6	10.11	0.60	8.14	19.96	61.19	2	4.54	0.59	1.47	12.75	80.64						
	'95-96	9	9.90	1.21	10.07	22.88	55.93	3	4.44	1.27	1.93	14.39	77.97						
	'00-01	11	9.46	1.47	10.36	25.39	53.33	4	4 46	1.57	2.03	15.95	75.99						



Delhi



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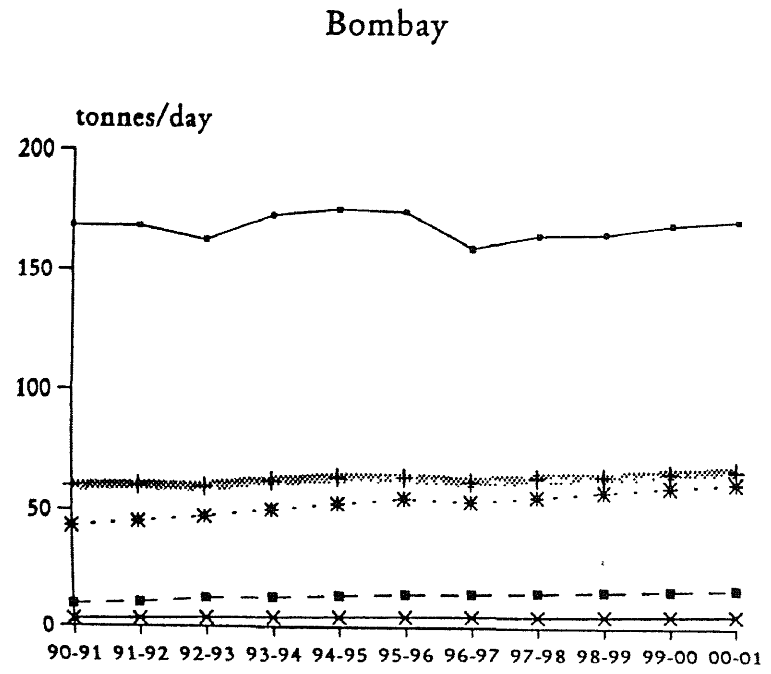
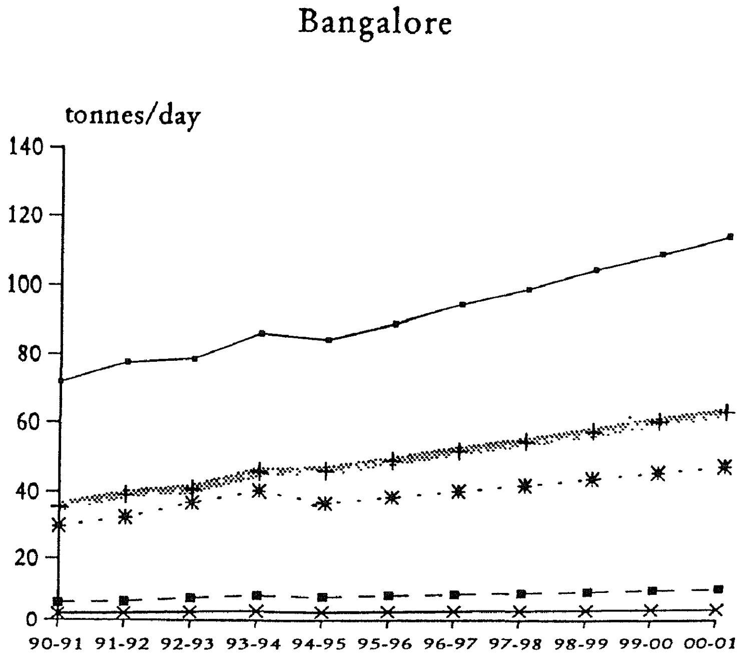


Bombay



Bangalore

respectively. The contribution of CO emissions in Delhi from two-wheeler (22%) and that of three-wheelers (24%) is relatively much higher than in Bombay and Calcutta. While in Bangalore contribution of CO emissions by different modes are relatively more evenly distributed with two-wheelers contributing to 30%, three-wheelers 26%, bus 23%, and car, jeep, and taxi 22% respectively.

Hydrocarbons

HC emission rates are higher in gasoline than diesel vehicles due to lower combustion efficiency in gasoline engines. Among the gasoline driven two and three-wheelers, two-stroke engines are highly inefficient as compared to the ones with four-stroke engines. Daily HC loading in 1995-96 was 164 t in Delhi, 44 t in Calcutta, 64 t in Bombay and 50 t in Bangalore. Each of these emission values are expected to increase to 205 t, 55 t, 68 t and 65 t respectively in 2000-01. Three-wheelers which run on two-stroke engines (with low combustion efficiency) contribute majority (over 42%) of HC emissions in each of the four cities. Two-stroke scooters and motor cycles also contribute significant emissions in Delhi (40%) and Bangalore (42%). However, cars, jeeps and taxis run on gasoline contribute sizable emissions after three-wheelers in Calcutta (22%) and Bombay (33%). Contribution of HC emissions from bus ranges between 5 and 8% in each of the four cities.

Nitrogen oxides

The emission rate of NO_x is higher in diesel heavy duty vehicles (like bus and commercial goods vehicles) because of lower combustion temperatures as compared to gasoline vehicles. NO_x emissions is likely to increase in each city. In 1995-96, daily emissions of NO_x was 104 t in Delhi, 44 t in Calcutta, 56 t in Bombay and 39 t in Bangalore. These figures are likely to go up to 129 t, 53 t, 63 t and 49 t respectively in 2000-01. Bus happens to be the major contributor of NO_x emission. Nearly 75% of the total NO_x emission in Delhi and Calcutta is due to bus. For Bombay and Bangalore the corresponding figures are 67% and 86% respectively. Gasoline driven car, jeep and taxis contribute almost the remaining NO_x contribution in each city, as the other modes i.e., two- and three-wheelers together contribute around 3% NO_x emissions.

Suspended particulate matter

Diesel vehicles emit significant SPM levels as compared to the gasoline vehicles. In 1995-96, daily emissions of SPM was 23 t in Delhi, 11 t in Calcutta, 15 t in Bombay and 9 t in Bangalore. Like other pollutants, SPM emissions also is likely to increase to 30 t, 14 t, 18 t and 11 t respectively during 2000-01. In Delhi and Bombay, major contributor of SPM emissions is bus, the share being 49% and 56% respectively, while in Calcutta and Bombay, car, jeep and taxi run on gasoline happen to be the main contributor with their share being 44% and 54% respectively. In each of these cities three-wheeler contribute in the range of 8-13%. Two-wheelers contribute around 14% of SPM emissions in Delhi, 10% in Bangalore, 4% in Calcutta and over 3% in Bombay.

Sulphur dioxide

Emission rate of SO_2 is higher in diesel than that of gasoline vehicles. During 1995-96, total daily emissions of SO_2 was 8 t in Delhi, 4 t in Calcutta, 5 t in Bombay and 3 t in Bangalore. Each of these values is expected to increase to 10 t, 5 t, 6 t and 4 t respectively. Bus happens to be the major contributor of SO_2 emissions in each city. Its share in Delhi is 72%, Calcutta 66%, Bombay 57% and Bangalore 78% respectively. Next comes car, jeep and taxi which contributes 19% in Delhi, 30% in Calcutta, 40% in Bombay and 14% in Bangalore. Less than 8% of the contribution share of SO_2 emissions is by two- and three-wheelers together.

Results and analysis under the two strategies

Energy demand and emissions are also estimated for 2000-01 under the two alternative scenarios 2 and 3 in each of the four cities. Results of each scenario is compared with the BAU scenario results discussed above.

Scenario 2

By facilitating a shift towards use of public buses, each city would save considerable oil in 2000-01 for passenger transportation. This would also lead into reduction in urban traffic congestion and emissions of CO, HC and SPM. However, emissions of NO_x and SO_2 would rise. Table 6 summarizes for each mode, percentage increase/decrease in gasoline and diesel requirement and emissions of different pollutants in scenario 2 in 2000-01 when compared with the BAU results. A 20% increase in bus share in the total travel demand in 2000-01 would lead to about 15% saving of oil for passenger transportation in Delhi (170696 toe) and Calcutta (67298 toe), 17% in Bangalore (59452 toe) and 22% in Bombay (128671 toe). The other advantages that ensue are 22% reduction of total vehicles on Delhi road, 39% in Calcutta, 41% in Bombay and 47% in Bangalore respectively. Emissions of CO and HC would decline considerably in each city. In Delhi, CO and HC emissions would reduce by 35% and 45% respectively. While in Calcutta drop would be 46% and 62%, Bombay 54% and 73% and in Bangalore 39% and 51% respectively. SPM emissions would also decline in each city, with maximum drop in Bombay by about 18% and least in Calcutta by 8%. However, emissions of NO_x and SO_2 would rise marginally in each city (with only exception being Bombay where SO_2 emissions would fall by around 3%). Rise in emissions of NO_x would lie in the range of 3% in Bombay and 10% in Bangalore. While that of SO_2 emissions would increase by around 5.5% in Delhi, Calcutta and Bangalore.

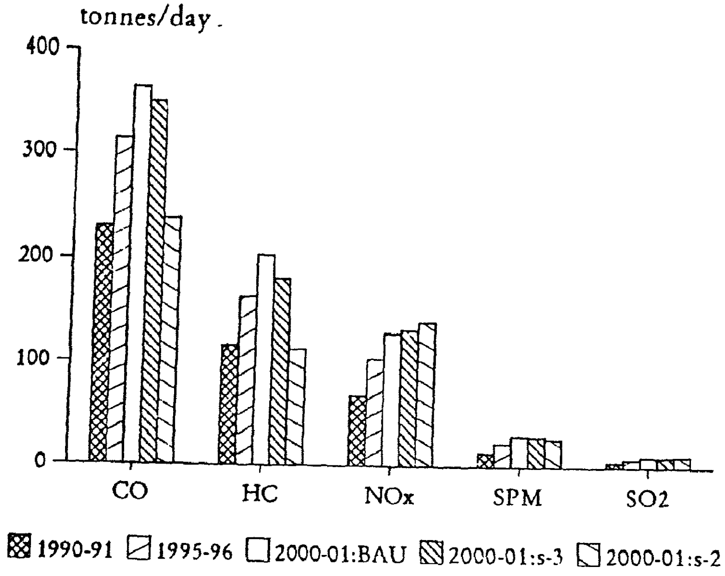
Scenario 3

Introduction of four-stroke two-wheelers by phasing out 45% two-stroke scooters in 2000-01 under scenario 3, would lead to a marginal reduction in total oil demand in each city when compared with the BAU case (Table 8). Though the reduction in gasoline demand by two-wheelers would be substantial. Similar trend is observed for emission reduction for CO, HC and SPM as given in table 7. In scenario 3, the total gasoline demand in Delhi would decline by around 1.2% (13364 toe), Calcutta 0.42% (1835 toe), Bombay 0.33% (1904 toe) and Bangalore 1% (3631 toe). Total CO emissions in Delhi would

Table 6. Reduction(-)/addition(+) in energy demand and emissions in 2000-01 under scenarios 2 and 3 when compared with the BAU scenario

Parametre	City	Results of scenario 2 compared with BAU								Results of scenario 3 compared with BAU		
		2-wheeler gasoline	3-wheeler gasoline	car, jeep & taxi		bus diesel	All modes together			2-wheeler only	total	
				gasoline	diesel		gasoline	diesel	gasoline & diesel		gasoline	diesel
Energy demand	Delhi	-20.5	-72.8	-23.7	-24.6	+20.0	-35.9	+13.2	-15.2	-9.20	-2.18	-1.19
	Calcutta	-51.9	-76.3	-32.7	-11.3	+20.0	-47.5	+11.6	-15.4	-8.35	-1.00	-0.42
	Bombay	-55.0	-99.8	-32.4	-28.1	+20.0	-47.9	+2.8	-22.3	-7.38	-0.72	-0.33
	Bangalore	-49.3	-57.6	-57.5	-25.5	+20.0	-54.7	+12.9	-16.7	-7.28	-2.52	-1.02
CO emissions	Delhi	-20.4	-72.8	-41.6	-24.6	+20.0	-45.7	+17.9	-34.5	-15.0	-4.5	-3.7
	Calcutta	-54.8	-76.3	-63.9	-11.3	+20.0	-67.3	+17.2	-46.2	-14.5	-2.2	-1.6
	Bombay	-57.3	-99.8	-61.2	-28.1	+20.0	-69.9	+13.7	-54.0	-12.8	-1.4	-1.1
	Bangalore	-52.8	-57.6	-56.2	-25.5	+20.0	-55.4	+17.8	-38.5	-10.4	-4.1	-3.2
HC emissions	Delhi	-22.0	-72.8	-46.4	-24.6	+20.0	-48.5	+16.8	-45.0	-28.8	-12.4	-11.7
	Calcutta	-55.7	-76.3	-70.4	-11.3	+20.0	-70.3	+15.8	-62.4	-26.1	-6.6	-6.0
	Bombay	-60.5	-99.8	-65.3	-28.1	+20.0	-80.9	+10.8	-73.1	-23.5	-5.5	-5.0
	Bangalore	-55.5	-57.6	-55.6	-25.5	+20.0	-56.5	+16.7	-51.4	-22.9	-10.7	-10.0
NO_x emissions	Delhi	-12.6	-72.8	-34.7	-24.6	+20.0	-36.5	+18.8	+8.3	+120.5	+14.0	+2.7
	Calcutta	-28.6	-76.3	-53.0	-11.3	+20.0	-54.3	+18.4	+8.1	+97.9	+6.3	+0.9
	Bombay	-26.2	-99.8	-51.3	-28.1	+20.0	-53.6	+16.3	+2.7	+75.8	+4.0	+0.8
	Bangalore	-24.2	-57.6	-57.5	-25.5	+20.0	-50.2	+18.8	+10.1	+67.6	+14.9	+1.9
SPM emissions	Delhi	-20.7	-72.8	-35.0	-24.6	+20.0	-42.9	+7.8	-9.7	-17.4	-6.9	-2.4
	Calcutta	-53.1	-76.3	-53.7	-11.3	+20.0	-63.9	+6.4	-7.5	-16.0	-3.7	-0.7
	Bombay	-57.4	-99.8	-52.0	-28.1	+20.0	-70.3	-5.9	-18.2	-14.4	-3.0	-0.6
	Bangalore	-49.9	-57.6	-57.4	-25.5	+20.0	-54.3	+7.3	-8.8	-16.1	-6.8	-1.8
SO_2 emissions	Delhi	-19.3	-72.8	-26.6	-24.6	+20.0	-30.3	+14.3	+5.6	+16.8	+5.2	+1.0
	Calcutta	-46.7	-76.3	-37.9	-11.3	+20.0	-45.0	+12.8	+5.5	+14.6	+2.5	+0.3
	Bombay	-48.0	-99.8	-38.0	-28.1	+20.0	-45.0	+4.9	-2.9	+12.4	+1.6	+0.3
	Bangalore	-43.4	-57.6	-57.3	-25.5	+20.0	-50.7	+14.0	+5.9	+11.9	+5.7	+0.7

Delhi



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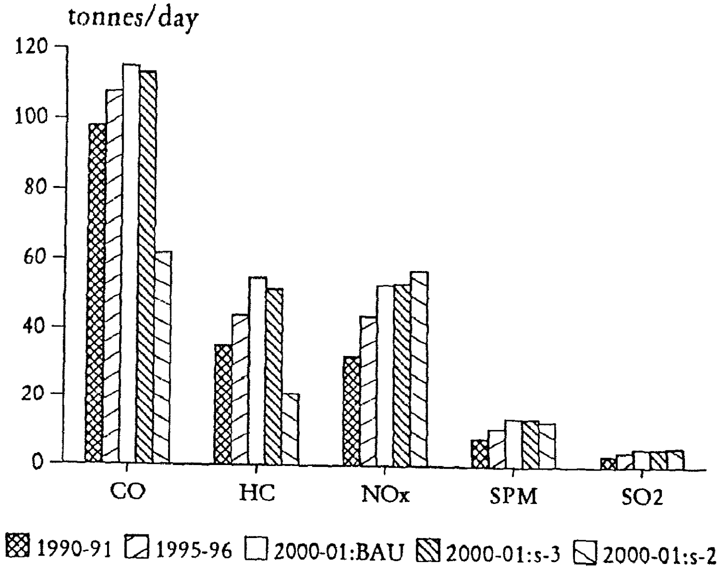
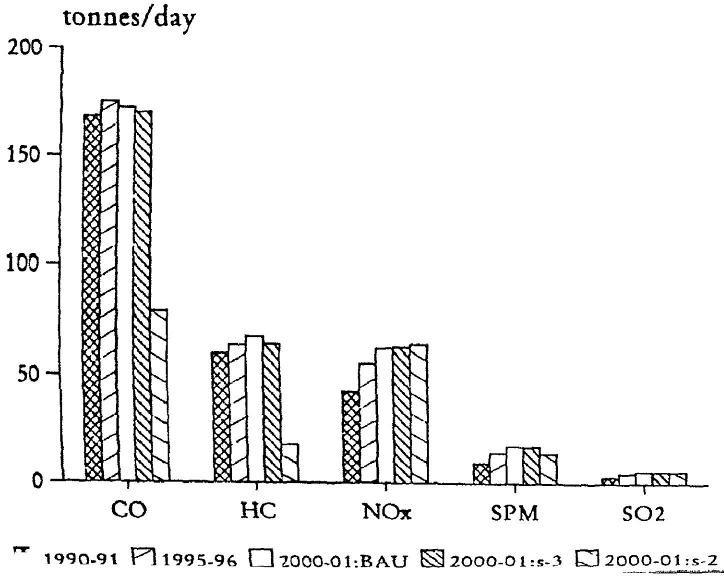
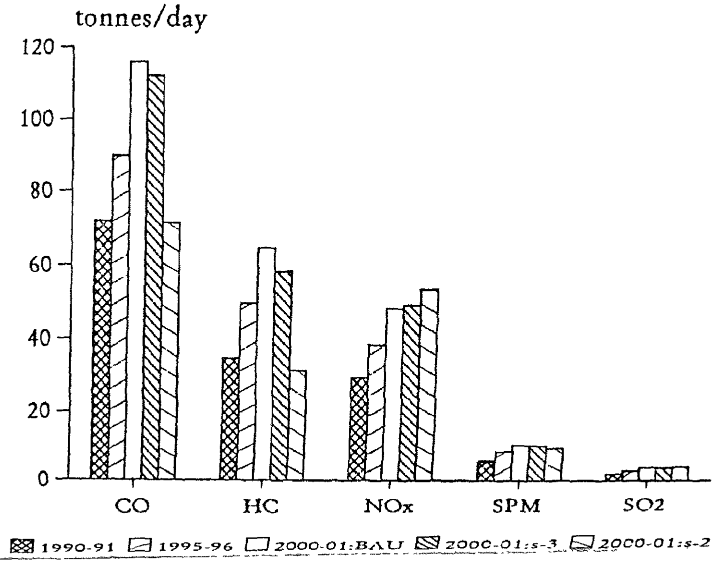


Bombay



Bangalore



decline by little less than 4%, Calcutta 2%, Bombay 1% and Bangalore 3% respectively. Similarly, emissions of total HC would reduce by 12% in Delhi, 6% in Calcutta, 5% in Bombay and 10% in Bangalore. Total SPM emissions would also drop in Delhi by 2%, Calcutta 0.7%, Bombay 0.6% and Bangalore nearly 2%. Emissions of the other two pollutants – NO_x and SO_2 would increase. In the former case, the range of increase would be 0.8% in Bombay to 2.7% in Delhi, while for SO_2 the rise would be in the range of 0.3% in Calcutta and Bombay to 1% in Delhi.

Figure 2 shows automotive emissions in the four cities in the past, present and future years (under alternative cases). High potential exists for stabilizing/reducing emissions of CO, HC and SPM with more buses on city roads. While, rate of decline in emissions is less when introduction of only clean technology as supply side intervention is considered. Thus, an increased reliance on demand management measures, complemented with supply intervention would help in improving the urban air quality.

Conclusions

The paper has illustrated the effect on emissions of two much discussed possibilities for improving economic efficiency while reducing energy demand and emissions in the four major metropolises in India:- (a) reducing urban congestion by facilitating a shift towards use of public transport and (b) introduction of clean technologies. The physical benefits in terms of oil savings and reduction in emissions have been quantified. Reduction in energy demand and emissions is substantial with more buses on road as compared to the gradual introduction of improved engine technologies. This suggests that the technological fix alone is not sufficient.

The current air quality strategy in developed economies is based primarily on a search for technological fix, which is a supply side option. However, in a rapidly growing developing economy like India, there are limitations to a strategy focused primarily on affecting automotive technology. With growing traffic congestion and inadequate investment in road development, demand management is critical and needs to be more vigorously used than at present, having usually failed due to: lack of public transport alternatives, lack of staff for design and enforcement; and political unwillingness to implement and enforce. It is desirable therefore, to complement the supply side interventions with demand management measures, if the ultimate objective is to secure improved levels of air quality.

Acknowledgement

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